State of Connecticut

FIRST BIENNIAL REPORT OF THE COMMISSIONERS

OF THE

State Geological and Natural History Survey

1903-1904

State of Connecticut

PUBLIC DOCUMENT No. 47

al and Natural Survey

RS

ecticut (*Chairman*)
Yale University
Wesleyan University
inity College (*Secretary*)
Connecticut Agricultural College

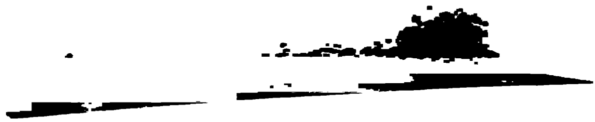
D 1

Ge
su
ar
bu
bo
is

wood & Brainar
1904

State of Connecticut

PUBLIC DOCUMENT No. 47



GEORGE S. G
LIBRARIA

J.

Dear

Geol
sure
are
bull
boun
issu

Tl ...ood & Brainard Company
1904

State of Connecticut

PUBLIC DOCUMENT No. 47

Conn.

State Geological and Natural History Survey

COMMISSIONERS

ABIRAM CHAMBERLAIN, Governor of Connecticut (*Chairman*)
ARTHUR TWINING HADLEY, President of Yale University
BRADFORD PAUL RAYMOND, President of Wesleyan University
FLAVEL SWEETEN LUTHER, President of Trinity College (*Secretary*)
RUFUS WHITTAKER STIMSON, President of Connecticut Agricultural College

SUPERINTENDENT

WILLIAM NORTH RICE

BULLETIN No. 1

HARTFORD PRESS
The Case, Lockwood & Brainard Company
1904

State of Connecticut

FIRST BIENNIAL REPORT OF THE COMMISSIONERS

OF THE

State Geological and Natural History Survey

1903-1904

State of Connecticut

PUBLIC DOCUMENT No. 47

GEORGE S. GODI
LIBRARIAN

J. C

Dear

Geolo
sure
are a
bulle
bound
issue

The Case, Lockwood & Brainard Company
1904

State of Connecticut

PUBLIC DOCUMENT No. 47

Conn.

State Geological and Natural History Survey

COMMISSIONERS

ABIRAM CHAMBERLAIN, Governor of Connecticut (*Chairman*)
ARTHUR TWINING HADLEY, President of Yale University
BRADFORD PAUL RAYMOND, President of Wesleyan University
FLAVEL SWEETEN LUTHER, President of Trinity College (*Secretary*)
RUFUS WHITTAKER STIMSON, President of Connecticut Agricultural College

SUPERINTENDENT

WILLIAM NORTH RICE

BULLETIN No. 1

HARTFORD PRESS
The Case, Lockwood & Brainard Company
1904

FIRST BIENNIAL REPORT OF THE COMMISSIONERS

OF THE

State Geological and Natural History Survey of Connecticut

1903-1904

Hartford Press
The Case, Lockwood & Brainard Company
1904

To His Excellency,

ABIRAM CHAMBERLAIN, *Governor of Connecticut:*

SIR: The Commission established by the General Assembly through "An Act Concerning the Establishment of a State Geological and Natural History Survey" present the appended report showing the progress and condition of the survey.

The Commission was organized at a meeting held June 15, 1903, pursuant to a call of the Governor of the State, and under his chairmanship.

All the members of the Commission designated by the Act of Establishment were present and accepted office.

The President of Trinity College was chosen Secretary.

At a meeting held June 25, 1903, Professor William North Rice of Wesleyan University was appointed Superintendent. The work described in the following pages has been carried on under his efficient administration.

Very respectfully,

FLAVEL S. LUTHER,

Secretary of the Commission.

HARTFORD, Dec. 23, 1904.

STATE GEOLOGICAL AND NATURAL HISTORY SURVEY.

APPOINTMENT OF SUPERINTENDENT.

The Act establishing the State Geological and Natural History Survey was approved June 3, 1903. The Commissioners under whose direction the Survey was placed by the terms of the Act, appointed, at a meeting held June 25, 1903, William North Rice, Professor of Geology in Wesleyan University, to be Superintendent of the Survey. A certain delay in the development of plans for the work of the Survey was inevitable. As the appointment to the Superintendency came to Mr. Rice unexpectedly, he was not able at once to decide whether, consistently with other duties, he could undertake the responsibilities of the office. Moreover, almost immediately after the date of his appointment, the gentlemen especially interested in the Survey, whom it was desirable to consult in regard to the plans for the work, were scattered for their summer vacations. It was, therefore, not until September 17th that Mr. Rice notified the Secretary of the Commission of his acceptance. In the course of the next few weeks plans for the work of the Survey were developed. At a meeting of the Commission, held on November 16th, a general plan of organization was adopted, and most of the lines of work to be undertaken were decided upon.

AIMS OF THE SURVEY.

The Survey is styled, in the Act for its establishment, a Geological and Natural History Survey. This title, and the still more explicit language of Section 2, we have understood as requiring that attention should be given both to the rocky framework of the state and to its vegetable and animal life — both to the Geology of the state and to its Botany and Zoölogy. The language of that section further implies that three distinct aims should be regarded in the work of the Survey: first, the advancement of our knowledge of the geology, botany, and

zoölogy of the state as a matter of pure science; second, the acquisition and publication of such knowledge of the resources and products of the state as will serve its industrial and economic interests; third, the presentation of the results of investigations in such form as to be useful in the educational work carried on in the various schools of the state. These three aims, the purely scientific, the economic, and the educational, we have endeavored constantly to keep in mind in all plans which have been made.

PLAN OF ORGANIZATION.

For various reasons, and especially in view of the small amount of the appropriation, and in view of the fact that the appropriation was made only for a single biennial term, with no definite promise of renewal, it seemed desirable that the organization of the Survey should be extremely simple. Under the conditions above mentioned it would have seemed unreasonable to create a long list of official positions with such titles as those of State Geologist, State Botanist, State Entomologist, etc. The establishment of a number of official titles of that sort would offer an expectation of permanent tenure to persons employed in the scientific work of the Survey, and would create an expectation that, in case those persons were not reappointed for the ensuing biennial term, there would be a number of official vacancies to be filled by the appointment of other persons. It was deemed desirable that the form of organization should be such as to imply no promises of any kind beyond the present biennial term. Accordingly, no appointment with official title has been made by the Commissioners in addition to the appointment of a Superintendent as provided explicitly in the Act establishing the Survey. Other scientific men have been employed to investigate specific subjects and to prepare reports thereon. In each case the Commissioners have fixed upon a certain sum as compensation, payable when the report in regard to the particular investigation is accepted. In addition to the sum appropriated as compensation, the Commissioners have appropriated in each case a certain sum to be drawn upon, so far as necessary, for payment of traveling expenses, services of stenographers and other assist-

ants, purchase of necessary apparatus and materials, and all other expenses incident to the prosecution of the work. The compensation of the Superintendent alone has been arranged in the form of a salary payable in quarterly instalments. A certain sum has been appropriated, also, for expenses of the Superintendent, to be drawn upon so far as necessary, as in the case of the other scientists employed on the Survey.

SCIENTIFIC WORK UNDERTAKEN.

The special works which have been undertaken may be classified in the three departments of Geology, Botany, and Zoology.

I. Geology.

1. A Manual of the Geology of Connecticut, so far as it is known at present. The former Geological Survey of Connecticut, which was established in 1835, ended its work with the publication of Percival's Report on the Geology of Connecticut in 1842. Considering the difficulties under which that Report was prepared, it will ever remain a monumental work in its minute accuracy of observation of the rocks of the state. At that time the science of dynamic geology was not yet far enough advanced to throw much light upon the interpretation of the geological phenomena of the state; and whatever theoretical views Percival may have held he seems to have almost entirely concealed. In the last half-century the science of geology in general has greatly advanced, and much more can be done now than then in the way of theoretical interpretation of the facts. Since the publication of Percival's Report a great deal of good geological work has been done in Connecticut, partly by men connected with the United States Geological Survey, and partly by those who have worked on their own responsibility. The results of that work, however, in so far as they have been published, are scattered through numerous volumes of government reports, scientific journals, and proceedings of learned societies. In this condition they are almost inaccessible to the great number of teachers in our high schools and other intelligent people in the state, who are not geologists by profession, but who desire to know something of the geo-

logical structure and history of the state. It was therefore believed that the preparation of such a manual as has been undertaken would be very useful, particularly in the line of education. Numerous conversations with teachers have yielded abundant evidence of the general demand for such a work. In some cases it will doubtless be put into the hands of classes as a text-book or book of reference, though it will be chiefly used by teachers. This work has been undertaken by the Superintendent of the Survey and Professor Herbert E. Gregory of Yale University, the former of whom contributes an introductory chapter on the relation of the geography of the state to its geological structure, and a chapter on the Triassic sandstones; while the latter contributes chapters on the crystalline rocks, and on the glacial geology of the state.

2. A Geological Map of the state, on a scale of four miles to the inch. This will be the first geological map of the entire state, in any considerable detail, which has been attempted since that of Percival in 1842. It is needless to remark on the value of such a map, whether from the standpoint of pure science or with reference to economic and educational purposes. The new map will contain all the topography which is given in the topographic map, on a scale of two miles to the inch, published in 1893 by the coöperation of the national government and the state government. The greater part of the so-called "culture" represented on that map, as roads, houses, etc., will be omitted, in order that the geological coloring may be put on without making the map confused. In central and western Connecticut sufficient data for a map on that scale had already been accumulated by the labors of the geologists employed under the direction of the United States Geological Survey, and the result of their work, whether published or unpublished, has been courteously placed at our disposal. In much of the eastern part of the state, however, there had been not even a geological reconnaissance since the time of Percival. The preparation of the map required, therefore, a large amount of field work in eastern Connecticut, which was accomplished, for the most part, in the summer of 1904. The preparation of this map has been undertaken by

Professor Herbert E. Gregory and H. H. Robinson, Ph.D., of Yale University.

3. An investigation of the Clays of Connecticut, both in their geological and in their economic relations. The importance of the manufacture of brick and tile, and other forms of clay industries in this state, renders such an investigation and report eminently appropriate. This investigation has been undertaken by G. F. Loughlin, B.S.

II. Botany.

1. An annotated list of the Phanerogams and the Higher Cryptogams of the state. Such a list will be, from the standpoint of pure science, a valuable contribution to our knowledge of botanical geography. In the notes due attention will be given to the economic relations of plants which are valued for their beauty or for their useful products, and to those which are troublesome weeds, or which possess poisonous or otherwise injurious properties. A short time before the organization of the Survey a society of the botanists of the state, both professional and amateur, had been formed under the name of the Connecticut Botanical Society. The members of this society, and especially committees representing the society, were already energetically at work gathering materials for such a Flora of the state. They responded most cordially to the suggestion that they find in the newly organized State Survey a medium for the publication of the results of their labor.

2. Reports on certain groups of the Fungi of Connecticut. This work has been undertaken by Professor E. A. White of the Connecticut Agricultural College and G. P. Clinton, Ph.D., of the State Agricultural Experiment Station in New Haven. The former of these authors is to report on the large, fleshy fungi (Hymeniales), some of which are valuable as food, while others are dangerous on account of their poisonous qualities. The latter is to report on the smuts (Ustilagineæ). These minute and lowly organized plants are of very serious economic interest, since among them are many destructive parasites of the plants which yield valuable agricultural products.

III. Zoölogy.

1. A list of the Birds of Connecticut, with notes in regard to their migrations, their food, and other matters bearing upon their economic relations. Besides the value of such a report as a contribution to the science of geographical distribution, the treatment which will be given of the economic relations of the different species of birds residing in our state or migrating through its territory will be of great importance for the agricultural interests of the state. This report will be, also, of great educational value, and will serve, in large degree, to encourage that loving study of bird life which has been of late years one of the most fascinating and wholesome phases of nature study. This work has been undertaken by Mr. John H. Sage of Portland, Secretary of the American Ornithologists' Union, and Dr. L. B. Bishop of New Haven.

2. A study of the Microscopic Life of the Fresh Waters of the state, and particularly of the reservoirs and other sources of drinking water. The State Board of Health has, indeed, published in former years the result of a good many analyses of drinking waters, and considerable information in regard to bacteria and other forms of minute life which have been observed in our waters; but there has been no attempt at any systematic enumeration or study of the forms of microscopic life existing in the waters. It seemed eminently desirable that a beginning should be made in that line of study, though it was obvious that it would be impossible to make any complete survey of our waters during the present biennial term. Apart from the purely scientific value of such investigation, it has been believed that the publication of a report with good figures of the principal forms of minute life in our waters would be of great educational value to the teachers of biology in our high schools, and to the large number of amateur students of microscopic life throughout the state. It appeared, also, not unlikely that such an investigation might yield results of economic importance in regard to means of avoiding the contamination of reservoirs by the presence of injurious or disagreeable organisms. This investigation has been undertaken by Professor H. W. Conn of Wesleyan University.

APPROPRIATIONS.

The amounts appropriated for the compensation of the various scientific men employed in the work of the Survey, and for the expenses of the different investigations, are indicated in the following table:

Name.	Work.	Compensation.	Expenses.
W. N. Rice,	Superintendence,	$400	$300
H. E. Gregory,	Manual of Geology of Connecticut,	150	50
H. E. Gregory and H. H. Robinson,	Geological Map,	450	200
G. F. Loughlin,	Report on Clays,	30	20
Conn. Botanical Society,	Flora of Connecticut,		100
E. A. White and G. P. Clinton,	Reports on Fungi,	200	100
J. H. Sage and L. B. Bishop,	Report on Birds,	200	200
H. W. Conn,	Study of Microscopic Fresh-water Life,	400	200

PROGRESS MADE.

In all the scientific labors which have been undertaken good progress has been made, and several of the reports are nearly or quite ready for publication.

The text of the Manual of Geology is nearly completed. Some work will be necessary in the preparation of illustrations before the work is ready for the printer. It will, however, in all probability be completed within a few weeks.

The field work for the Geological Map of Connecticut was accomplished by Professor Gregory and Dr. Robinson, with the assistance of Mr. Loughlin, in the summer of 1904, and a manuscript map will be ready to be placed in the hands of the engraver at an early date.

Mr. Loughlin's report on the Clays of Connecticut is nearly ready for publication.

The Connecticut Botanical Society has made good progress in the preparation of the Flora of the state.

The reports of Professor White and Dr. Clinton on certain groups of Fungi will be ready for the printer within a few weeks.

Mr. Sage and Dr. Bishop have made good progress in their work on the Birds.

A preliminary report on the Protozoa of our fresh waters has been placed by Professor Conn in the hands of the Superintendent. The drawings for the illustration of this work have already been given to the engraver. They are to be reproduced inexpensively but effectively by a photographic process.

PLAN OF PUBLICATION.

Each Report prepared is to be published as a separate Bulletin, the Bulletins to be numbered consecutively, generally in the order of time in which they are received. Each Bulletin will bear the name of the author or the names of the authors, and each author will be responsible for his own work.

The various Bulletins will be issued in paper covers, but a portion of the edition will be reserved for binding. From time to time the Bulletins which have been published will be assembled in volumes of convenient size, generally not less than five hundred pages, nor more than one thousand. The colleges, public libraries, geological surveys, and learned societies to which the publications will be sent, and, in general, the institutions in which it is likely that complete sets of the publications of the Survey will be preserved, will have the option of receiving the separate Bulletins as they are published, or of receiving at less frequent intervals the bound volumes.

An arrangement has been made with the State Library which will be mutually beneficial to the two institutions. The State Librarian has kindly undertaken to give attention to the distribution of the publications of the Survey; and the publications which are received in exchange from other geological surveys and from various learned societies and scientific institutions will be deposited in the State Library. In this way it is believed that the operations of the Survey will lead to the acquisition of much valuable material for the State Library.

LEGISLATION DESIRED IN REGARD TO PUBLICATION OF REPORTS OF THE SURVEY.

The general law of the state limits the edition to be printed of any report to 1,375 copies, in the absence of any special legal

provision for a larger edition. Such a number will be altogether inadequate for the distribution which should be made of the reports of the Survey. Such reports issued by other states are widely distributed to colleges, scientific institutions, public libraries, scientific men, teachers, and others. The editions printed are never less than 1,500, and generally range from 3,000 to 8,000. It is very desirable that such reports should be liberally distributed to citizens of the state whose economic and educational interests they are intended to advance. A careful consideration of the classes of persons and institutions that should be reached by the publications of the Survey, and a consideration of the usage of similar organizations in other states, lead to the conclusion that not less than 3,500 copies should be published in the case of most of the Bulletins of the Survey; and that in some cases the edition should be considerably larger than that number. The Manual of Connecticut Geology, and the Report of Messrs. Sage and Bishop on the the Birds of Connecticut, will be so largely used by the teachers of the state in their work that we believe an edition of 4,500 copies of each of these Bulletins should be published. As has been already indicated, some of the Bulletins are substantially ready for the printer, and others will be ready within a few weeks. It is therefore earnestly desired that the General Assembly, at as early a date as may be practicable, pass an act authorizing the printing of 3,000 copies of this, the regular Report of the Survey; 4,500 copies of two of the special reports, namely, the Manual of Connecticut Geology, and the Report on Birds; and 3,500 copies of the other special reports of the Survey.

PLANS FOR FUTURE WORK.

While it would be useless and inexpedient to attempt anything like an enumeration of all the scientific investigations of the resources and products of our state which should be made in future years, it may be fitting to give some intimation of reasonable plans for work in the near future, that the members of the General Assembly may be better prepared to reach a wise conclusion in regard to the continuance of the appropriation for the work of the Survey.

In geology it may be said that the study of a large part of the area of the state has been little more than reconnaissance. Numerous and perplexing problems in the geology of the state demand laborious investigation. The Manual of Geology and the Geological Map which are being prepared for publication must be considered rather as reports of progress than as final reports upon the geological structure of the state. They will be useful, indeed, but a large part of their usefulness will be in the aid which they will afford to future study, by which their errors will be rectified and their deficiencies will be supplemented. The Geological Map which is being prepared for publication gives only the formations of consolidated rock of pre-Quaternary age, omitting all reference to the glacial drift and the aqueous and aqueo-glacial deposits associated with it. A publication which should be attempted at an early date is a map of the surface geology of the state. While Connecticut is not rich in metallic ores which can be profitably exploited, it possesses a vast wealth in its building stones. A most suitable subject for investigation and report under the auspices of the State Survey would be the building stones of the state. Another report might well deal with the mineralogy of the state. Many of the localities of the state have long been famous for rare and interesting minerals, but no attempt has been made in recent times to compile and present in available form the knowledge of such localities.

The annotated Flora of the state which is being prepared by the Connecticut Botanical Society will be of great value, but it is only the beginning of work which may in future be done in the department of botany. Particularly there is a demand for extensive study of the plants of the state in their relations to the inorganic and organic conditions which constitute their environment. The distribution of the plants with reference to altitude, geological formation, distance from the sea, temperature, and rainfall, and the grouping of plants into plant societies in different areas of the state, are among the subjects which demand investigation. Besides the work which should be done upon the higher plants, attention should be given to the plants of lower organization, many of which are

of great economic importance. A beginning has been made in this direction, but only a beginning. Professor Conn and his assistant, Miss L. W. Hazen, have done some work on the fresh-water Algæ, on which a report will probably be ready for publication at an early date; but that report, when it appears, will be only a preliminary report. A vast amount of work yet remains to be done. The Bacteria of our waters are of profound significance, both scientifically and economically. The perils involved in the presence of pathogenic bacteria in reservoirs and other sources of drinking water, and the problems connected with the pollution of rivers by sewage, give to this group of organisms a portentous importance. Professor Conn has already done a considerable amount of work on the bacteria of our waters, but the investigation is not so far advanced as to afford results suitable for publication. The work of Professor White and Dr. Clinton on certain groups of the Fungi is a good beginning, but is very far from being a completion of the work which a State Survey may rightly undertake in this department.

In zoölogy, one line of work very important in both scientific and economic relations has not been entered upon at all by the present State Survey; that is the department of economic entomology. The study of the insects injurious or beneficial to the agriculture of the state is a field demanding a vast amount of investigation. Professor Conn's Report on the Protozoa of our fresh waters is justly styled "a Preliminary Report." It is very desirable that the work which has been so well begun should be continued. Besides the Protozoa there are other minute forms of animal life in our fresh waters whose systematic study has not been commenced. In a state which has so long a line of sea-coast as Connecticut, and whose fishery industries are so important as ours, a State Survey may well be expected to do a large amount of work in marine zoölogy — a field which the present Survey has not yet attempted to enter.

The advance of science, while it solves some problems, suggests new problems. The changes which are continually being made in the processes of the arts and manufactures bring into use from time to time, and create a demand for, new forms

of raw material. The study of the resources and products of any area takes on new meanings with the progress of science and art. The work of the past must be supplemented by new studies in each generation.

It must be remembered that the state of Connecticut has had no Geological or Natural History Survey since that of Shepard and Percival from 1835 to 1842. It is indeed true that the state of Connecticut coöperated with the United States Geological Survey in the preparation of the invaluable topographical atlas of the state. Much valuable scientific work, also, has been done by the State Board of Health, Board of Agriculture, and Agricultural Experiment Stations, and other organizations. But no attempt in the direction of systematic study of the resources and products of the state has been attempted for about two generations. In the mean while, many of our sister states have maintained and are still maintaining Geological and Natural History Surveys, which have issued publications of great scientific value and of great utility to the arts and industries in which scientific knowledge finds practical application. The work which has been done in accordance with the Act of the General Assembly in the session of 1903 is only a beginning. If it was wise then to establish a Survey, it is wise now to provide the necessary appropriation for its continuance.

State of Connecticut

State Geological and Natural History Survey

BULLETIN No. 2

A PRELIMINARY REPORT

ON

THE PROTOZOA OF THE FRESH WATERS OF CONNECTICUT

By

HERBERT WILLIAM CONN, Ph.D.,

Professor of Biology in Wesleyan University

State of Connecticut

PUBLIC DOCUMENT No. 47

State Geological and Natural History Survey

COMMISSIONERS

HENRY ROBERTS, Governor of Connecticut *(Chairman)*
ARTHUR TWINING HADLEY, President of Yale University
BRADFORD PAUL RAYMOND, President of Wesleyan University
FLAVEL SWEETEN LUTHER, President of Trinity College *(Secretary)*
RUFUS WHITTAKER STIMSON, President of Connecticut Agricultural College

SUPERINTENDENT

WILLIAM NORTH RICE

BULLETIN No. 2

HARTFORD PRESS
The Case, Lockwood & Brainard Company
1905

A PRELIMINARY REPORT

ON

THE PROTOZOA OF THE FRESH WATERS OF CONNECTICUT

By

HERBERT WILLIAM CONN, Ph.D.,
Professor of Biology in Wesleyan University

Hartford Press
THE CASE, LOCKWOOD & BRAINARD COMPANY
1905

A Preliminary Report on the Protozoa of the Fresh Waters of Connecticut.

By H. W. Conn, Ph.D.,

Professor of Biology, Wesleyan University.

INTRODUCTION.

In connection with the State Geological and Natural History Survey, I have been requested to undertake the study of the microscopic life in the waters of the State. This part of the State Survey is naturally a very extensive piece of work, and at the present time only the beginnings of the task can be reported.

The work, as it has come into my hands, has divided itself into three parts.

1. The Protozoa.
2. The Algae and allied plants.
3. The Bacteria common in the waters of the State.

Work upon all three of these divisions of the subject has been undertaken, and is progressing satisfactorily. Up to the present time most of my own attention has been given to the study of the Protozoa. This part of the work has been carried on extensively since its assignment to me, and has reached a point where it is deemed wise to present a preliminary report upon the work already done.

Hitherto a comparatively small amount of study has been given to the Protozoa in American waters. The only extensive contributions to the studies of our Protozoa have come from Stokes* and Leidy.† In addition there have been a number of isolated publications upon the various genera and

* A Preliminary Contribution toward a History of the Fresh Water Infusoria of the United States. Journ. Trent. Nat. Hist. Soc., I, 1888.

† Fresh Water Rhizopoda of North America, Washington, 1879.

species. Prof. Stokes' valuable papers are, at present, somewhat difficult to obtain, and very difficult to follow, because of the lengthy and somewhat obscure descriptions that are given of his different species. His figures, however, are usually satisfactory, and make it possible for a student to identify his species, comparing them with forms which may be under examination. Besides the works of Stokes and Leidy there are only a few scattered papers describing isolated genera and species found in America. This dearth of work makes the study and description of American types of Protozoa especially desirable, in order that there may be in the hands of microscopic students a complete description of the types of Protozoa which are liable to be found in American waters. Such a publication does not, at present, exist. Prof. Stokes' papers have described only newly discovered species, and have never attempted to give any descriptions of forms which he simply identified and which have been described elsewhere. The literature upon Protozoa is in general so widely scattered that it is not accessible in any convenient form to the student of American microscopy. It is, therefore, a great desideratum that the description of all types of American Protozoa should, if possible, be collected and published together for the use of American students. A description of Connecticut species will not, of course, completely fill this need, but will come nearer to it than any previous publication.

For these reasons it has seemed to me that before it is possible to attempt a study of the distribution of Protozoa in the waters of the State, or of any problems associated with their economic relation to the purity of drinking waters, considerable preliminary work must be done which shall include a study and description of the genera and species found in this region. This part of the work has occupied most of my attention during the past year.

The time that it has been possible to put upon the work during the last year has been sufficient to accumulate a large amount of data upon this general subject, and it is probable that I have now obtained and had an opportunity of studying most of the genera of Protozoa liable to be found in Connecticut. This is certainly true of the two groups, FLAGELLATA and INFUSORIA.

Upon the rarer groups, Rhizopoda, Heliozoa, and Suctoria, my work is less complete, and the forms already found probably do not constitute so large a proportion of the whole as in the other two groups.

It is, of course, perfectly evident that even this preliminary work is not yet complete. It will require a long-continued study of the waters of the State before a complete list and description of all the Protozoa can be given. Before this can be regarded as complete it will doubtless be necessary to obtain the coöperation of microscopists in other localities in collecting material and possibly studying the same. The completion of the work can therefore only be made after some years of study. For this reason it is thought to be wise to publish at the present time a preliminary report upon the Protozoa already found, in order that such a report may be used to stimulate the study of this group by other microscopists in the State, and thus increase the amount of work that can be done and the territory that can be covered. The present report is designed, therefore, simply as introductory, and its purposes are, 1st, to state the progress that has been made in the study of the Protozoa, and 2d, to elicit the coöperation of other microscopists so far as possible. It is hoped, therefore, that microscopists into whose hands this preliminary report may fall and who may be interested in the study of the microscopic life of our waters, will communicate with the author of this paper, in order that, if possible, coöperative work may be started in various parts of the State. The author would be very glad to receive communications from any one within the limits of the State who is interested in microscopic study, and especially to obtain material for study that anyone will be kind enough to send to his laboratory in Middletown.

It is expected that, at a later time, a more complete report of the Protozoa of the State will be published, which, it is hoped, may take the form of a general scientific study of the unicellular animals and their evolution, as illustrated by the forms found in our own waters. Such a study is not feasible at present. The present report is planned with the object of making it as useful as possible to microscopists. Therefore it has been regarded as wise to illustrate carefully all species

found. In the study of Protozoa careful figures are always of more value to the microscopist than specific descriptions, because of the difficulty in studying the animals and tracing out minute details. It frequently happens that one can easily recognize a species from its appearance, when it would be impossible to determine the characters upon which the species or even the genus is based. In the study of a rapidly moving microscopic animal it is often impossible to make out minute details, and points in internal structure, — like the nucleus and vacuoles — cannot, in many cases, be decided upon in the living specimens. In all such cases the general appearance of the animals is of more use in determination than specific descriptions. For this reason there is given, in the present report, a figure of every species of animal thus far thoroughly identified, and, in some cases, two or three figures of the same type are given where specimens show considerable variations from each other. The figures are all original, and drawn by the author from the actual specimens.

The *key* printed in this preliminary report is designed for the use of working students, and is not intended to indicate any real relations of the organisms in question. The problem of the general relations of the groups will be discussed when a more complete report of the Protozoa may be prepared. This key is based upon one which has been found most useful to the author, namely, the one published by Kirchner and Blochmann.* The key, as printed in the following pages, follows in general the one devised by these authors. It has, however, been much modified, to make it clearer and more useful to a beginner. Inasmuch as quite a number of genera are clearly present in our waters which are not included in the above-mentioned key, it has been found necessary to add these new genera to the key. It is believed, therefore, that our key is an improvement over any before published. This key includes all the genera known to occur in fresh water, whether they have yet been detected in Connecticut or not, and, consequently, all that are likely to be found in our State.

* Die Mikroskopische Pflanzen- und Thierwelt des Süsswassers, Braunschweig, 1886.

Following the key I have given brief diagnostic descriptions of the determined *genera*. In these descriptions I have also followed the plan of Kirchner and Blochmann, in including only the essential characters, leaving out the subordinate details which are liable to confuse the student rather than aid in identification. In the description of the genera only those are described in this preliminary report which have already been actually identified by myself, as occurring in our waters. There are doubtless other genera in Connecticut, which will be found later, and their descriptions will be given in subsequent reports.

I have found several types of Protozoa existing in our waters, sometimes in considerable abundance, that do not agree with any described genera. Whether to regard these as new genera or modified forms of described genera I am as yet uncertain. In this preliminary report they are called *new genera*, and descriptions are then given. No attempt is made at present to give them names, for I regard it preferable to reserve the final descriptions and the naming of such types until a later report, when a longer period of study may enable me to determine more accurately whether these genera are connected by intermediate grades with any of the types already described, or whether they should be regarded as really new.

Descriptions of *species* are wholly omitted in this report. The Protozoa are known to be widely variable, and it is, therefore, always a matter of great difficulty to determine where to draw the limits between species. Two different attitudes toward this question may be adopted. One is to describe each distinguishable type as a separate species, and the other to group large numbers of closely allied forms together under the name of one species, even though they show wide variations. The latter method appears to me, on the whole, preferable; but if it is to be done, it can only be done after a long study of the different varieties that may be found, a study much more extended than it has been possible as yet to give to the subject. Moreover, the specific descriptions of Protozoa are so widely scattered in literature that it is a great task to obtain them all. Up to the present time I have not been able to search all this literature, in order to identify all the species

which I have found. Wherever I have been able clearly to identify the specific names, or the probable specific names, of the animals described, I have given these names in the following report, but in cases where I have not yet determined the species I have always indicated it by the sign *sp* (?). Some of the species thus marked are doubtless new species. It has been evident in the course of the study that it is possible to create many *new species* out of the types found in Connecticut, if it is so desired. But in the present report it is not thought wise to do this. In the later report the discussion of the question of species will be given more thoroughly.

The figures which accompany this report are drawn to scale, so as to be directly comparable in size. In the RHIZOPODA and INFUSORIA, Plates I-V and Plates XI-XXXIV, the figures are all magnified 500 diameters, except in a few cases where otherwise noted. In the FLAGELLATA, Plates VI-X, the figures are magnified 1,000 diameters, unless otherwise stated. A few very large animals could not be so highly magnified, and where such is the case the amount of magnification is stated on the figure. There is a certain disadvantage in drawing to the same scale figures of animals differing so widely in size, since it makes it impracticable to arrange figures on the plates in their proper order in all cases. Using the same scale, also, makes some figures unnecessarily large and others too small for the best results. But the practical advantage to the student of learning directly from the figures the relative size of all the animals figured is very great. This advantage of being able to determine the relative sizes at a glance, rather than needing to make a calculation for the purpose, has appeared to me to offset very decidedly the disadvantages that come from using figures of such varying sizes.

Nearly all the specimens described in this paper have been found in the waters of Middletown. Collections of materials have also been made from other localities in the State, and many of the species described have been identified elsewhere. A few of the specimens described have been found in other towns, but not yet in Middletown, although probably nearly all types of Protozoa will be found more or less uniformly distributed over the State. This question of *distribution* will not,

however, be considered in this preliminary report. The waters which have furnished the specimens have been largely drinking waters of Middletown and other cities, although a considerable amount of material has been obtained from brooks and rivers, road-side pools, and even watering troughs.

THE PROTOZOA.

The Protozoa are divided into classes, as follows:

1\. Animals partly free, partly attached, with pseudopodia, flagella, or cilia 2

Animals, when adult, attached usually by a stalk; the free portion provided with a small number of stiff knobbed projections, which can be withdrawn, called tentacles .... SUCTORIA p. 65

2\. Adult animals with pseudopodia 3

Adult animals with flagella or cilia 4

3\. Pseudopodia of variable form; sometimes with a shell either homogeneous or made of plates, sand grains, etc .... RHIZOPODA p. 11

Pseudopodia stiff, finely thread-like, seldom branched or anastomosing, arranged radially around the spherical body; sometimes with an envelope of jelly, or a skeleton of silicious needles ....
HELIOZOA p. 17

4\. With 1-2, rarely 3-4, long flagella, and one nucleus
MASTIGOPHORA p. 19

With a large number of cilia and one or more nuclei .... CILIATA p. 39

CLASS RHIZOPODA.

Key to Genera.

1\. No shell 2

With a shell 9

2\. Pseudopodia lobe-like 3

Pseudopodia fine, reticular, arising in groups......
Gymnophrys

3\. No nucleus 4

With nucleus 5

4. Without contractile vacuole .... *Protamœba?*†
With contractile vacuole .... *Gloidium?*†
5. One pseudopodium directed forwards ..... *Hyalodiscus**
Pseudopodia more than one 6
6. Pseudopodia finger-like, from the border only, or from one or few parts of the spherical body 7
Pseudopodia various but from all sides of the body .. 8
7. Discoidal; pseudopodia radiating from all sides .... *Dactylosphærium*
Spherical; pseudopodia from one spot; commonly violet .... *Amphizonella*
8. Pseudopodia many, lobe-like, from all sides of the body .... *Amœba**
Pseudopodia many, fine, membrane-like; ectosarc reddish .... *Plakopus*
Pseudopodia few, very broad; animals large....... *Pelomyxa**
9. Pseudopodia finger-like 10
Pseudopodia thread-like 18
10. Shell chitinous, colorless or yellowish, with a structure only visible with high powers............. 11
Shell with evident structure, either secreted by the animal or made of foreign bodies 15
11. Shell watch-glass shape; pseudopod opening on under side 12
Shell ellipsoidal, compressed, structureless *Hyalosphenia*
12. Shell hyaline 13
Shell showing hexagonal markings 14
13. Pseudopod opening large, not closed by a membrane; pseudopods many .... *Cochliopodium*
Pseudopod opening closed by a membrane as far as the pseudopodia; shell flexible....... *Pseudochlamys*
Pseudopod opening narrowed by an evident border *Pyxidicula*
14. With a variable number of spines .... *Centropyxis**
Without spines; shell yellow or brown .... *Arcella**
15. Shell made of sand grains, diatom shells, etc. ...... *Difflugia**

* Genera already found in Connecticut and described in the following pages.
† Doubtful genera.

Shell chitinous with a few grains of sand at one end *Heleopera*
Shell with no sand grains 16
16. Body spiral .... *Lecquereusia**
Body not spiral 17
17. Shell made of four-sided plates; pear-shaped.. *Quadrula**
Shell of round, irregular, chitinous plates; compressed; with a two-lipped mouth .... *Nebela*
18. Shell with one pseudopod opening 19
Shell with two pseudopod openings 27
19. Shell with evident structure 20
Shell without evident structure 23
20. Shell made of grains of sand 21
Shell chitinous but encrusted with sand grains; retort-shaped, with two lateral processes above .... *Campascus*
Shell chitinous, without sand grains 22
21. Pseudopodia of one kind............... *Pseudodifflugia*
Pseudopodia of two kinds............. *Diaphoropodon*
22. Shell circular, compressed; mouth irregularly notched .... *Assulina*
Shell pear-shaped or spherical; compressed; made of rounded, spirally arranged plates, giving an hexagonal appearance; mouth with toothed plates.... *Euglypha**
Shell as above, but with mouth excentric ...... *Trinema*
Shell with finer markings; neck bent to one side .... *Cyphoderia**
23. Solitary 24
Mostly colonial 25
24. Mouth lateral; shell thin, flexible; pseudopodia arising from a stalk in the mouth .... *Lieberkuhnia*
Mouth terminal; shell ovate to spherical, or flattened; pseudopodia partly reticular, partly branched, slightly anastomosing, and extending around the body .... *Gromia*
Mouth terminal; shell very delicate; pseudopodia not extending around the body .... *Pamphagus**
25. Shell close to the body; spherical........... *Lecythium*
Shell not close to the body 26

26. Shell delicate; body with a granular central zone; individuals united by the pseudopodia ...... *Platoum*
Shell delicate; body without central zone; with a short neck and a lateral mouth .... *Microgromia**
27. Shell of sand grains .... *Amphitrema*
Shell without sand grains 28
28. Shell delicate; two lateral pseudopod openings; with yellow to red oil drops .... *Diplophrys**
Shell chitinous; with two terminal pseudopod openings .... *Ditrema*
Shell chitinous, spherical; with many pore-like openings .... *Microcometes*

Description of Genera.

Hyalodiscus H. & L.

Round to elongated disk-shaped; without evident pseudopodia; moving without much change in shape. Nucleus and contractile vacuole always present.

Hy. limax Duj., Figs. 2, 8.

Hy. guttula Duj., Figs. 3, 4.

Amœba Ehrbg.

Usually a sharp differentiation of ectoplasm and entoplasm. One large nucleus or many small nuclei present, and also one or more contractile vacuoles. Pseudopodia generally lobe-like, seldom branched. Reproduction by division in motile stage.

Am. proteus Leidy, Fig. 1.

Am. verrucosa Ehrbg., Figs. 5 and 6.

Pelomyxa Greeff.

With broad, sack-like pseudopodia; ectosarc apparent only in places; hyaline; entosarc vacuolated. Nuclei numerous. With fine hyaline rods, which often form a covering over the body.

Fig. 7 is, with some doubt, referred to this genus, its small size rendering its identification uncertain. It is, perhaps, only a species of *Hyalodiscus*.

Dactylosphærium H. & L.

Body round; pseudopodia ray-like, arising from all sides of the disk-formed body; short lobe-like pseudopodia,

frequently arising after the withdrawal of the ray-like pseudopodia. Nuclei and contractile vacuoles always present.

Dac. radiosum Ehrbg., Fig. 9.

Arcella Ehrbg.

Shell yellow to dark brown, watch-glass shape, curved or polyhedral. The side bearing the psudopodia flat, with central opening. The shell shows a fine hexagonal lattice-work, due to its being made of hexagonal prisms. Body substance does not completely fill the shell. Nuclei and vacuoles usually numerous. Reproduction by fission and budding.

Arc. dentata Ehrbg., Figs. 10 and 10a.

Arc. vulgaris Ehrbg., Fig. 11.

Centropyxis Stein.

Like *Arcella*, but armed with a variable number of spines. This genus is closely related to *Arcella*, and is commonly regarded as the same.

Cent. aculeata Stein, Fig. 13.

Quadrula F. E. Sch.

Shell pear-shaped, slightly compressed; composed of quadrilateral (silicious?) plates. Posterior end sometimes armed with spines.

Q. symmetrica Schul., Fig. 20.

Difflugia Leclerc.

Shell formed of foreign bodies, grains of said, diatom shells, etc., united by a chitinous connecting substance. Form spherical to pear-shaped; frequently with spines at the posterior end. Mouth occasionally excentric. Body not completely filling the shell; with finger-like pseudopodia. Nucleus and contractile vacuoles variable.

Dif. globosa Duj., Fig. 14.

Dif. lobostoma Leidy, Fig. 16.

Dif. pyriformis Perty, Fig. 17.

Dif. cratera Leidy, Fig. 19.

Dif. acuminata Ehrbg., Fig. 22.

Dif. corona Wall., Fig. 27.

Lecquereusia Schlumbg.

Shell of sand or specially formed bodies. Shell spirally coiled, laterally compressed, but the neck cylindrical.

Lec. (*Difflugia*) *spiralis* Ehrbg., Fig. 12.

Euglypha Duj.

Shell of round, oblique rows of plates, whose edges cross to make hexagonal areas. Shell spherical to pear-shaped. Spines frequently present. Mouth surrounded by regular teeth. Body differentiated into a finely granular posterior portion and a coarsely granulated anterior portion. Pseudopodia fine and frequently branching.

Eug. alveolata Duj., Fig. 24.

Cyphoderia Schlumbg.

Shell retort-formed, with an oblique opening, composed of five six-sided plates. Body differentiated into two divisions, the anterior containing the vacuole and the posterior the nucleus.

Cy. ampulla Ehrbg., Fig. 15.

Microgromia H. & L.

Usually united in colonies. Shell colorless, flask-formed, with short neck. Pseudopodic openings slightly to one side. Body incompletely filling the shell. Base of pseudopodia slightly lateral, with contractile vacuole at its base. Pseudopodia delicate, anastomosing, with streaming granules. Commonly forming colonies.

Fig. 21 is, with some doubt, referred to this genus.

Pamphagus Bai. (*Lecythium,* H. and L.)

Much like *Microgromia.* Shell delicate, flexible, and lying closely upon the body. Body not evidently divided into two regions. Pseudopodia delicate, without granules.

Pam. (*Lecythium*) *hyalinum* H. & L., Fig. 30.

Diplophrys Barker.

Shell spherical to ellipsoidal, with two pseudopodic openings, not exactly in the body axis. A nucleus and many contractile vacuoles present. Usually with one large, or with two or more small yellow to red fat globules. Pseudopodia in two groups, delicate, slightly branched, and not anastomosing.

Dip. archeri Barker, Fig. 29.

CLASS HELIOZOA.

Key to Genera.

1. No outer envelope.............................. 2
   Outer envelope present.......................... 6
2. Body commonly amœboid; pseudopodia either from all sides or from one place; no axial fiber....... 3
   Spherical; pseudopodia from all sides, with axial fiber 5
3. Ectoplasm and entoplasm not differentiated; colorless 4
   Ectoplasm and entoplasm differentiated; the first hyaline, and the latter red or brown. Commonly red cysts on algæ......................*Vampyrella**
4. Nuclei one or more; several slowly pulsating vacuoles; solitary...........................*Nuclearia**
   Colonies of eight or less; pseudopodia with spindle swellings ....*Monobia*
5. The vacuolated ectoplasm not sharply separate from entoplasm; central nucleus............*Actinophrys**
   Ectoplasm with large vacuoles, sharply separate from entoplasm; many nuclei; 1 mm. in size......... *Actinosphærium*
6. Envelope jelly-like; streaked, punctured, or folded.. 7
   Envelope of isolated silicious pieces, or a silicious shell 8
7. Envelope punctured, with fine radiating spines between the pseudopodia.................*Heterophrys*
   Envelope of streaked appearance, lobe-like surface; colonial ....*Sphærastrum*
8. Envelope of many layers of silicious globules...... *Pompholyxophrys*
   Envelope of loose and more or less bent silicious needles; commonly colonial.........*Raphidiophrys**
   Envelope of leaf-like, pointed silicious plates...... *Pinaciophora*
   Envelope of radiate spines, with a basal plate...... *Acanthocystis*
   Envelope of silicious shell, with rounded openings.. *Clathrulina**

Description of Genera.

Vampyrella Cienk.

Ectoplasm hyaline, entoplasm usually brown or red; frequently vacuolated. Form amœboid, changeable, spherical, disk-formed, or elongated. Pseudopodia ray-like, either arising on all sides or at one point. One or more nuclei; contractile vacuole not definitely made out. Frequently there is found a gelatinous covering through which the pseudopodia protrude.

Vamp. lateritia Fres., Fig. 25.

Nuclearia Cienk.

Body spherical, disk-formed or elongated. Pseudopodia from all sides, or arising only in one place; sometimes branching. One or more nuclei, and many contractile vacuoles. Sometimes surrounded by a gelatinous envelope.

Nu. simplex Cienk., Figs. 18 and 23.

Actinophrys Ehrbg.

Usually spherical with pseudopodia on all sides, whose axial thread can be traced to the nucleus lying in the granular entosarc. The colorless ectoplasm not sharply differentiated from the entoplasm. Usually a single contractile vacuole. Multiplication by division. Occasionally colonial.

Act. sol Ehrbg., Fig. 26.

Rhaphidiophrys Arch.

Solitary or colonial. Spherical with delicate pseudopodia uniform over the body. No sharp differentiation of the body substance. Nuclei, one or more, and several contractile vacuoles. Skeleton composed of irregular, loosely bound, straight or slightly bent silicious needles, mostly tangential to the body surface and frequently raised around the bases of the pseudopodia. Colonies have a common shell. Sometimes with chlorophyll bodies.

Rhap. elegans H. & L., Fig. 31.

Clathrulina Cienk.

Animals like *Actinophrys,* without differentiation into body regions, with numerous contractile vacuoles, central nucleus, and many delicate pseudopodia frequently forked

at the end. Skeleton a silicious shell nearly spherical, containing numerous round or polygonal openings. Attached by a long, tubular stock, whose root-like base is fastened to other objects. The young shell colorless, but later brown. The animal moves freely in its shell by means of its pseudopodia.

Clath. elegans Cienk., Fig. 28.

CLASS MASTIGOPHORA.

The classification of the *Mastigophora* adopted below is essentially that of Bütschli. It does not represent genetic relationship so well as a classification adopted by Senn (Engler and Prantl, Pflanzenfamilien) based upon the type of metabolism. But the older classification, based upon the flagella, is more convenient to use and is of more practical value in the identification of types. For this reason it has been adopted in this preliminary report.

Key to Orders.

With one or more flagella, without a collar, and without a transverse furrow..............FLAGELLATA, p. 19

With one flagellum whose base is surrounded by a collar.. CHOANOFLAGELLATA, p. 38

With two flagella, one of which lies in a cross furrow, and the other in a longitudinal furrow directed backwards. Sometimes naked and colorless; sometimes with a tabulated armor, colored green, yellow, or brown by chromatophores ...........DINOFLAGELLATA, p. 39

ORDER FLAGELLATA.

Key to Sub-Orders.

1. One flagellum, or several flagella, mostly directed forward 2

   Usually two flagella of different sizes, one of which is directed forwards and the other backwards.... HETEROMASTIGODA, p. 29

2. Mostly small, with one large flagellum and frequently one or more smaller secondary flagella.......... MONADINA, p. 20

Larger animals, commonly with one large flagellum, sometimes with two such flagella, or with a single large flagellum and a secondary one. Mouth and commonly a pharynx at the base of the flagellum .... EUGLENOIDINA, p. 24
With two or more equal flagella ....
ISOMASTIGODA, p. 32

SUB-ORDER MONADINA.

Key to Genera.

1. Possessing both flagella and pseudopodia; readily passing into a Heliozoid stage 2
   Commonly without pseudopodia; with one flagellum 3
   Without pseudopodia; with one flagellum, and one or two secondary flagella 8
2. One evident flagellum and lobe-like or pointed pseudopodia .... *Mastigamœba**
   In flagellate stage, with one or two flagella; in Heliozoid stage, without flagella .... *Ciliophrys*
   Two flagella in both stages; pseudopodia simple, with axis fiber .... *Dimorpha*
   Two flagella in both stages; pseudopodia various, without axis fiber .... *Cercobodo**
3. Without lorica 4
   With lorica 6
4. Posterior end elongated into a tail; sometimes amœboid .... *Cercomonas**
   No tail, although sometimes narrowed posteriorly; free or attached; flagellum vibratile..... *Oikomonas**
   Body ovate, flattened, free; flagellum usually carried obliquely forward and vibratile only at its end... *Notosolenus**
6. Solitary 7
   Colonial; daughter-individuals attached to inner wall of lorica .... *Poteriodendron*
7. With a peristome process .... *Bicosœca*
   Without a peristome process .... *Codonœca*
8. Without chromatophores 9
   With yellow to brown chromatophores 13

9. Forming branching colonies.................... 11
Solitary 10
10. Free, or attached by an attenuated posterior end; moderately flexible; one or two secondary flagella ....*Monas**
Free, attenuated in front; very flexible; no secondary flagellum ....*Leptomonas**
With the anterior flagellum replaced by a flexible tentacle ....*Rhynchomonas**
11. Many individuals upon the end of each branch..... 12
One individual on the end of each branch..*Dendromonas*
12. Stalk short, branching dichotomously once or twice *Cephalothamnium**
Stalk well developed; the older animals brown, granular ....*Anthophysa**
13. Colonial 14
Solitary 15
14. Lorica horny with pointed posterior end; colonies formed by growth from rim of lorica; colonies free ....*Dinobryon**
Colonies of numerous individuals in a gelatinous sphere ....*Uroglena**
15. Without lorica ....*Ochromonas**
With horny lorica..........................*Epipyxis*
With a shell made of overlapping plates bearing long spines ....*Mallomonas**

Description of Genera.

Mastigamœba F. E. Sch.

Form amœboid. Ectoplasm sometimes differentiated. Pseudopodia finger-like to acute, rarely branching. A nucleus and one or more contractile vacuoles present. One prominent flagellum. Upon assuming the free-swimming stage the pseudopodia disappear.

M. reptans Stokes, Fig. 32.

M. longifilum (?) Stokes, Fig. 33.

Cercobodo Krass.

Body spherical to spindle-formed, amœboid. Two flagella, of which one is trailing. Motion free or creeping

in flagellate stage, and by pseudopodia in the amœboid stage. One or two contractile vacuoles, one lying in front and the other behind; nucleus anterior.

C. mutabilis (?) Stokes, Fig. 36.

Cercomonas Duj.

Form spherical to spindle-shaped, colorless. A single long anterior flagellum. Body prolonged posteriorly into a caudal process. Pseudopodia frequently seen, particularly near the caudal process. Nucleus in anterior half of body; one or more vacuoles.

C. longicaudata Duj., Fig. 34.

C. crassicauda Duj., Fig. 35.

Oikomonas S. K.

Very small. Free swimming or attached by a protoplasmic filament. Spherical, oval, or amœboid. With one flagellum on anterior end and near by frequently a projecting lip which serves for taking food. Nucleus and contractile vacuole present.

O. sp (?), Fig. 40.

O. sp (?), Fig. 40*a*.

Notosolenus Stokes.

Oval or angular; flattened dorso-ventrally with dorsal side concave. Rigid. One long flagellum carried obliquely and stiffly in front, and a shorter one only ⅓ the length of the body directed backwards and commonly not visible. Mouth near base of flagellum. Contractile vacuole double.

N. orbicularis Stokes, Fig. 37.

N. sp (?), Fig. 38.

N. sp (?), Fig. 39.

Monas Ehrbg. Stein.

Solitary; spherical to ovate. Occasionally fastened by a delicate stalk-like posterior end. With one chief flagellum and one or secondary flagella. A mouth projection and occasionally an eye-spot present. A nucleus near the flagellum and one or two contractile vacuoles.

M. (Physomonas) elongata (?) Stokes, Fig. 41. Attached and free.

Leptomonas Kent.

Solitary, attenuated in front, very flexible, and carrying one long flagellum. Usually parasitic.

Fig. 42, representing an animal found in the water of a watering trough, is with some doubt referred to this genus.

Rhynchomonas Klebs.

Ovate, slightly compressed, the anterior end prolonged into a movable process. Slightly contractile. The single flagellum trailing. Mouth near the anterior end. Contractile vacuole anterior; nucleus central. Motions slow.

R. nasula Klebs, Fig. 65.

Cephalothamnium Stein.

Body elongated, with an obliquely truncated anterior end that forms an acute projection on one side. One chief flagellum about as long as the body, at whose base is a small secondary flagellum and a mouth. Nucleus and contractile vacuole anterior. Forming colonies in groups upon the end of a stalk, either simple or branching twice or three times.

C. cæspitosa (?) S. K., Fig. 46.

Anthophysa Bory de Vinc.

Animals as in *Cephalothamnium*. Forming spherical colonies upon the ends of a much branched stalk, the older portions of which are brownish and the younger portions colorless.

A. vegetans Stein, Fig. 47.

Dinobryon Ehrbg.

Free swimming colonies, yellow to brown. A beaker-like lorica, with an acute posterior end. The younger individuals are mostly attached with their posterior end inside of the mouth opening of the older individuals. With two chromatophores and an eye-spot. Central nucleus and one or two anterior contractile vacuoles. One primary and one secondary flagellum.

D. sertularia Ehrbg., Fig. 44.

Uroglena Ehrbg.

Free swimming, nearly spherical colonies, made of many individuals embedded on the surface of a jelly-like

mass. Individuals like *Dinobryon,* usually with two yellow chromatophores and an eye-spot. Nuclei central and an anterior contractile vacuole. One primary and one secondary flagellum.

U. americana Calk., Fig. 49. The cause of a fishy taste frequently found in reservoirs.

Mallomonas Perty.

Oval to enlongated, solitary, with a shell made up of overlapping plates bearing long spines. One prominent flagellum. Two yellowish green chromatophores, but no eye-spot. Many posterior contractile vacuoles, and an elongated anterior nucleus.

M. acaroides Perty, Fig. 58.

M. sp (?), Fig. 60. Cross section, Fig. 60*a*.

SUB-ORDER EUGLENOIDINA

Key to Genera.

1. One evident flagellum (two similar flagella in Eutreptia) 2
   One chief and one secondary flagellum.......... 15
   Typically colored.......... 3
   Typically uncolored.......... 12
3. Naked, or with very thin cuticle.......... 4
   With cuticle usually striated; flexible or rigid; sometimes with lorica or shell.......... 7
4. Numerous small green chromatophores.......... 5
   Two yellow or green chromatophores.......... 6
5. Without trichocysts..........*Cœlomonas*
   With trichocysts..........*Goniostomum*
6. Two lateral brown chromatophores, each with one eye-spot; mouth opening and vacuole system present ....*Microglena*
   One or more yellow chromatophores; one eye-spot and many contractile vacuoles at base of flagellum *Chromulina**
   Two green chromatophores; one eye-spot.......... *Cryptoglena**
7. Flexible; free swimming, with a delicate shell, or fixed in a lorica, or on a stalk.......... 8

Not flexible or only slightly so; with a thick cuticle 11

8. Without a lorica.............................. 9
With a lorica.............................. 10

9. With one flagellum; both ends contracted.....*Euglena**
With one flagellum; anterior end rounded; usually in a jelly-like envelope, and attached by a branched stalk; ectoparasites.......................*Colacium*
With two flagella.........................*Eutreptia**

10. In a beaker-shaped or tube-like lorica........*Ascoglena*
In a hard, smooth or spiny, spherical or cylindrical, brownish shell.....................*Trachelomonas**

11. Ellipsoidal or slightly flattened; pharynx in body axis, and a short, pointed caudal process..*Lepocinclis**
Ellipsoidal, not flattened; with rows of tubercles and a pointed caudal process..............*Chloropeltis**
Usually asymmetrical, flattened. Mouth on back; pharynx oblique; evident, pointed caudal process *Phacus**

12. Not flexible.............................. 13
Flexible.............................. 14

13. Elongated, somewhat crescentic; rounded posterior end ....*Menoidium*
Straight, spindle-formed; acute posterior end...... *Atractonema**
Cylindrical, slightly bent; both ends rounded...... *Rhabdomonas*
Much flattened, with one or more keels upon dorsal surface; large mouth at base of flagellum.*Petalomonas*

14. Long, needle-shaped; frequently spiral......*Astasiopsis*
Oval, flattened; mouth at base of flagellum; an evident pharynx and a rod-like organ........*Peranema**
Flask-shaped; neck-like anterior end, with pharynx extending to middle; rod-like organ present..... *Urceolus**
Like *Urceolus*, but covered with sand grains....... *Urceolopsis*

15. Flexible 16
Not flexible.............................. 17

16. Like *Euglena* in shape and method of contraction; secondary flagellum small, close to chief flagellum *Astasia**

Oval or elongated; secondary flagellum commonly directed backwards ....*Zygoselmis*

17. Elongated or crescentic; with four acute, longitudinal ridges, and hence nearly four-sided....... *Sphenomonas**

Like the above, but without the longitudinal ridges.. *Clostonema**

Nearly ellipsoidal, with many slightly spiral ridges.. *Tropidoscyphus*

Description of Genera.

Cryptoglena Ehrbg. = *Chloromonas* S. K.

Rigid, flattened, with two lateral green chromatophores, a single eye-spot, a mouth, and vacuole system. Nucleus posterior.

C. pigra Ehrbg., Fig. 93.

Euglena Ehrbg.

Large flagellates, spindle-formed or elongated, widely variable; usually with a strong, spirally marked cuticle. Frequently the whole animal moves with a screw-like motion. Body very flexible. Chromatophores green, either disk-shaped and numerous, or star-shaped or ribbon-like, and in small numbers; commonly without pyrenoids. In many species the animals are colored red; less frequently there are found quite colorless individuals. Mouth and pharynx evident, and a long flagellum arising from the mouth which, however, frequently drops off. At the lower end of the pharynx is a vacuole system with an eye-spot close by. Nucleus present, as well as paramylum bodies.

Eu. viridis Ehrbg., Fig. 45.

Eu. sp. (?), Fig. 50.

Eu. deses Ehrbg., Fig. 51.

Eu. spirogyra Ehrbg., Fig. 56.

Eu. sp. (?), Fig. 57.

Eu. sp. (?), Fig. 52. This animal is sufficiently flexible to bend from side to side, but does not show the peculiar

euglenoid movements of this genus. I place it here with some doubt, although it does not agree with any other genus known to me.

Eutreptia Perty.

Like *Euglena,* but with two equal flagella. When extended, body is spindle-formed and very flexible. A delicately marked cuticle. The body contains disk-formed chromatophores without pyrenoids; paramylum bodies cylindrical.

Eut. viridis Perty, Fig. 48.

Trachelomonas Ehrbg.

Animals like *Euglena;* free swimming, with a rigid spherical to ovate or cylindrical lorica which is either smooth, sculptured, or spiny. Lorica colorless, or colored red to brown. The flagella three to four times as long as the body. Disk-formed chromatophores with pyrenoids and paramylum bodies present.

Tr. lagenella (?) Stein, Fig. 53.

Tr. hispida Stein, Fig. 54.

Tr. volvocina Ehrbg., Fig. 59.

Lepocinclis Perty. = *Chloropeltis* Stein.

Ellipsoidal, round or slightly compressed, with prominent longitudinally or spirally marked cuticle, sometimes armed with spines. Near the flagellum a short tube, or a short pharynx. Posterior end acute. Paramylum bodies sometimes large and snake-like.

Lep. sp. (?), Fig. 61. This animal, found abundantly, is with some doubt referred to this genus, the short caudal extremity being unlike the typical forms of *Lepocinclis.*

Phacus Nitzsch.

Usually much flattened, asymmetrical, round to oval or pear-shaped. Commonly with a sharply differentiated, colorless, caudal process which is sometimes oblique. Mouth on the back; cuticle thick and marked by longitudinal or spiral stripes. Chromatophores and paramylum bodies disk-shaped. One flagellum, with the vacuole system and eye-spot, as in *Euglena,* and a posterior nucleus.

Ph. pyrum Ehrbg., Fig. 62.

Ph. pleuronectes Nitzsch, Fig. 63.

Ph. sp. (?), Fig. 64.

Chloropeltis

Body as in *Lepocinclis,* but with the longitudinal spirals armed with spines.

Ch. hispidula Stein-Eichwald, Fig. 55.

Menoidium Perty.

Colorless, sickle-form, with posterior end rounded; anterior end prolonged into a neck and obliquely truncated. The short side of the body thin and sharp, the long side rounded. Pharynx and vacuole system present, and a posterior nucleus.

M. tortuosa Stokes, Fig. 87. This is *Atractonema tortuosa* of Stokes, but it appears to differ from *Menoidium* only in having an acute posterior end.

Peranema Duj.

In the extended condition the body is oval, with a broad, rounded posterior end. Very flexible. A fine spirally marked cuticle. Flagellum very long, broader at its base, and vibrating chiefly at its tip. A mouth opening behind the flagellum which extends into a short, tube-shaped pharynx. A peculiar rod-like organ back of the mouth. Vacuole system at base of the flagellum, and a central nucleus.

Only one species of this genus has been hitherto described, but the different forms shown below evidently belong to this genus, and show too great variations to warrant putting them under one species.

P. trichophorum Ehrbg., Fig. 74.

P. sp. (?), Fig. 70.

P. sp. (?), Figs. 71 and 71*a*.

P. sp. (?), Fig. 72.

Urceolus Meresch.

In an extended condition body somewhat flask-shaped, with a contracted neck; posterior end rounded; anterior end forming a funnel-shaped peristome from which the flagellum protrudes and which extends into a pharynx reaching to the posterior third of the body. A rod-like organ present as in *Peranema.* Nucleus and contractile vacuole present.

U. cyclostomus (?) Stein, Fig. 69.

Astasia Stein.

Body elongated, spindle-formed, very flexible, spirally striated or smooth. Mouth and pharynx evident, as in *Euglena.* Close beside the large flagellum a very small secondary flagellum. Nucleus and contractile vacuole present.

As. sp. (?). Fig. 73, is probably *Astasia,* although the secondary flagellum was not evident.

As. contorta (?) Duj., Fig. 103.

Sphenomonas Stein.

Not flexible; body ellipsoidal with four strong keels, giving the body a somewhat four-sided cross section. A chief and a secondary flagellum and a pharynx present. See *Clostonema* below.

Clostonema Stokes.

Fusiform to elongate, not contractile. Two unequal flagella, one carried forward and the other backward. Pharynx present. Contractile vacuole double; anterior nucleus central.

Cl. socialis Stokes, Figs. 88 and 90. This is regarded by Senn as belonging to the genus *Sphenomonas* of Stein, but the absence of keels seems to separate the two, and I have, therefore, retained Stokes' genus, *Clostonema.*

SUB-ORDER HETEROMASTIGODA

Key to Genera.

1. Small animals sometimes showing amœboid motions; no evident cuticle 2
   Larger and possessing a cuticle; body frequently flattened 7
2. Flagella two 3
   Flagella three .... *Elvirea**
3. Both flagella directed forwards .... *Dinomonas**
   One flagellum directed backwards, trailing 4
4. Anterior end oblique; mouth at base of flagella .... *Phyllomitus**
   Body spiral .... *Spiromonas**
   Body neither oblique or spiral 5

5. Trailing flagellum in a furrow; motile flagellum terminal .... *Colponema*
Trailing flagellum not in a furrow................ 6
6. Food taken in by a dorsal vacuole........ *Pleuromonas**
Food not taken in by a dorsal vacuole............ *Bodo**
7. Trailing flagellum in a mouth furrow, extending in a curve around the end and passing backwards on the right side of body; body not flexible.. *Anisonema**
Like *Anisonema*, but with flexible body...... *Metanema**
Like *Anisonema*, but with trailing flagellum more posterior .... *Heteronema**
Like *Anisonema*, but with the trailing flagellum close to the motile flagellum, and with a very evident, partly protrusible pharynx............. *Entosiphon**

Description of Genera.

Bodo Ehrbg. = *Heteromita* Stokes.

Small, without a lorica; pear-shaped to spindle-shaped, with one flagellum directed forward, and a trailing flagellum. Mouth at base of flagellum. Pharynx frequently developed. Nucleus and contractile vacuole present. Many species assume an amœboid stage.

Stokes has described a large variety of forms under the name *Heteromita*, that must be classed with this genus. Many of his species I have identified as very common in our water.

B. ovata Stokes, Fig. 77.

B. sp. (?), Fig. 78.

B. globosa Stokes. Figs. 79 and 96 perhaps represent different species.

B. variabilis Stokes, Figs. 82-85.

B. acus Stokes, Fig. 86.

Pleuromonas Perty.

Kidney-shaped to spherical, slightly amœboid. One anterior flagellum and a second in the middle of the ventral depression. Contractile vacuole anterior, nucleus posterior. Frequently attached by the posterior flagellum. Food absorbed by a dorsal vacuole.

Pl. jaculans Perty, Fig. 66.

Dinomonas Kent.

Agreeing with *Bodo* in most respects. In moving both flagella are carried forward.

D. vorax (?) Kent, Fig. 67.

Phyllomitus Stein.

Ovate, elongate, very flexible. A prominent mouth opening in front; with two flagella, one directed forward, the other backward. One anterior, contractile vacuole; nucleus anterior. Motions quick.

Ph. amylophagus (?) Kleb., Fig. 68.

Spiromonas Perty.

Body elongated and spirally twisted. Both flagella arise in front, one of them trailing.

The genus *Spiromonas* of Perty is insufficiently described for identification. Our specimen is certainly not the one described by Perty, but would seem to be properly placed in the genus *Spiromonas.*

S. sp. (?), Fig. 110.

Elvirea Parona.

Ovate to elongate, laterally compressed. Three flagella, the middle one the shortest, the other two trailing. Mouth and nucleus anterior.

El. cionæ Parona, Fig. 100.

Anisonema Duj.

Body generally nearly oval, flat and asymmetrical, rigid. The ventral side with a depression extending toward the right, which is guarded by a lip on its right-hand border. The motile flagellum arises from the middle of the anterior end, and behind it is a mouth-opening leading into a long pharynx. The prominent trailing flagellum arises on the left side in the mouth depression, and extends around the front end in a curve, to pass backward upon the right side of the above-mentioned lip. Vacuole system anterior and nucleus further back.

A. acinus Duj., Fig. 80.

A. sp. (?), Figs. 75, 76.

Metanema Klebs.

Like *Anisonema,* but with body flexible.

M. sp. (?), Fig. 81.

Heteronema Duj.

Like *Anisonema,* but with second flagellum larger and point of origin somewhat more posterior; body with oblique mouth depresison.

H. sp. (?), Fig. 94. Fig. 94*a* is side view. Of the generic identification of this animal I am in doubt.

Entosiphon Stein.

Similar to *Anisonema.* Ventral side with a strong medial furrow. Both flagella arise in a slight depression in the anterior end. The trailing flagellum is directed backwards and is not so well developed as in *Anisonema.* Pharynx very long, extending to the hind end of the body; protrusible. Contractile vacuole, secondary vacuoles, and a nucleus present.

En. sulcatus Duj., Fig. 89.

SUB-ORDER ISOMASTIGODA

Key to Genera.

1. Solitary 2
   Colonial 19
2. Uncolored 3
   Colored 11
3. With two flagella.................................... 4
   With four flagella.................................... 7
4. Body laterally expanded into two wings, each with a flagellum ....*Trepomonas**
   Body not laterally expanded.................... 5
5. Body sometimes attached by a stalk; not flattened, and with no cuticle....................*Amphimonas**
   Body never attached by a stalk; with a cuticle...... 6
6. Body much flattened, anterior end oblique; pharynx not evident ....*Cyathomonas**
   Body less flattened, and with an evident pharynx.... *Chilomonas**
   Body ellipsoidal, not flattened; pharynx not evident, but with a well-developed cuticle.........*Polytoma**
7. With a deep ventral furrow..............*Collodictyon*
   Without ventral furrow.................... 8

8. Body in a lorica, oval.................... *Tetraselmis*
Body not in a lorica............................ 9
9. With an evident peristome................. *Tetramitus*
Without evident pharynx........................ 10
10. With three flagella carried forward, the other trailing *Trichomastix**
With four anterior flagella and two flagellum-like processes at posterior.................. *Hexamitus**
11. With two flagella................................ 12
With four flagella........................... *Carteria*
12. Attached to a stalk, or in a lorica................ 13
Free swimming.................................. 14
13. Upon a long stalk, with two brown chromatophores *Stylochrysalis*
Urn-shaped lorica; attached to algæ....... *Chrysopyxis*
14. With band-shaped, brown chromatophores 15
With green chromatophores..................... 16
15. Broad kidney-shaped; flagella in an anterior furrow; one chromatophore; movement lateral.... *Nephroselmis*
Elongated, acute posteriorly; two chromatophores and a thick cuticle; pharynx not evident *Ochromonas**
Elongated, laterally compressed, with evident pharynx *Cryptomonas**
16. Spherical 17
Not spherical.................................... 18
17. With delicate, closely attached cuticle; spherical to elliptical; one chromatophore...... *Chlamydomonas**
With delicate cuticle, separate from the mass of the body .... *Hæmotococcus**
With rough cuticle, separate from the mass of the body .... *Coccomonas*
18. Lenticular, with a two-valved cuticle.......... *Phacotus*
Elongated, spindle-shaped; two ribbon-like chromatophores .... *Chlorangium**
Spindle-shaped; body uniformly green.... *Chlorogonium*
19. Uncolored 20
Colored 21

20. Colonies gelatinous, thread-like, discoidal or round, hollow or sack-like.................. *Spongomonas*
Colonies of dichotomously branching tubes..*Cladomonas*
Colonies of many closely approximating, jelly-like tubes .... *Rhipidodendron*

21. With two brown, band-like chromatophores........ 22
With green chromatophores..................... 23

22. Spherical swimming colonies; cuticle sometimes spiny *Synura**
Like the above but with a common jelly covering... *Syncrypta*

23. Colonies commonly spherical..................... 24
Colonies not spherical.......................... 25

24. Colonies of sixteen (rarely thirty-two) radially arranged individuals, their inner ends reaching the center .... *Pandorina**
Colonies of sixteen individuals, separate from each other, and lying near the wall of the jelly sphere.. *Eudorina*
Colonies of very numerous individuals in a sphere.. *Volvox*†

25. Colonies of eight equatorially arranged individuals.. *Stephanosphæra*
Colonies somewhat ellipsoidal, of sixteen individuals, in four rows around a longitudinal axis......... *Spondylomorum**
Colonies of four to sixteen individuals in a flat plate . *Gonium*

Description of Genera.

Amphimonas Duj.

Spherical to oval, or triangular. Posterior end elongated into a thread-like stalk, which may be attached. Two equal flagella arise at the anterior end close together

† *Volvox* is frequently included among the FLAGELLATA, and certainly shows resemblances to some of the genera belonging to this class. I have, therefore, included it in this key, although I regard it as more closely related to the ALGÆ. Its description will be reserved for the paper upon the ALGÆ, which will appear later.

or far apart. One or two contractile vacuoles and a nucleus.

Am. sp. (?), Fig. 117. This is a form found very abundantly, but, so far as seen, never attached as in the typical species of *Amphimonas*. The two equal flagella would seem to place it here.

Trepomonas Duj.

Somewhat spherical or flattened, with two mouths on opposite sides of the body. The two sides are prolonged into wings projecting posteriorly. These wings are contracted near the body so that a cross section of the animal is in the form of an S. In the anterior end of each wing arises a long flagellum directed forward; also three very small secondary flagella. Nucleus anterior, contractile vacuole posterior.

T. agilis Duj., Fig. 115.

Cyathomonas From.

Much flattened, somewhat oval, with an obliquely truncated anterior end, bearing two equal or nearly equal flagella. Parallel with the anterior border is a row of highly refracting bodies. Contractile vacuole anterior, nucleus central.

Cy. truncata From., Fig. 111.

Cy. sp. (?), Fig. 112. The lower figure shows a side view.

Chilomonas Ehrbg.

Somewhat oval, contracted posteriorly; laterally compressed. Anterior end obliquely notched. Upon the upper side of the notch arise two flagella. The mouth leads into a tube-like pharynx extending to the middle of the body. Colorless, with an anterior contractile vacuole and a posterior nucleus.

Ch. paramecium Ehrbg., Fig. 91. An extremely common species.

Ch. sp. (?), Fig. 95. A smaller type with differently shaped body, far less common than the first species. It may be only a variety of the more common species.

Polytoma Ehrbg.

Mostly ellipsoidal, with a delicate shell and two flagella; colorless; occasionally a slightly colored eye-spot.

At the base of the flagellum two contractile vacuoles. Nucleus posterior; usually with many starch grains in the posterior part of the body. Multiplication by fission (inside of the shell) into four or eight parts which then become free.

P. uvella Ehrbg., Fig. 101.

Hexamitus Duj.

Body ellipsoidal, somewhat flexible. The anterior end rounded or acute, with two flagella. The posterior end either truncated or prolonged into two thread-like caudal processes. The animals appear very variable in form. Nucleus near the flagella and contractile vacuole posterior.

H. inflatus Duj., Fig. 97. Fig. 98 is probably a variety of the same, and also Fig. 113.

H. spiralis (?) Stokes, Fig. 105.

Trichomastix Bütsch.

Pear-shaped to elongated, rounded in front, acute behind. In front four flagella, of which three are usually carried close together, appearing as one, while the other is commonly carried behind as a trailing flagellum. The anterior flagella may be separated as shown in the figure.

The animal figured in Fig. 118 does not appear to resemble any described genus, but I place it here as being more like *Trichomastix* than any other genus. *Trichomastix* is described as parasitic. Our animal was found in great numbers in a watering trough.

Ochromonas Wys.

Oval to pear-shaped, amœboid. One long and one secondary flagellum. Mouth at base of flagellum. One or two yellowish chromatophores and an eye-spot. Anterior contractile vacuole and central nucleus. Free swimming or attached.

Och. sp. (?), Fig. 43.

Cryptomonas Ehrbg.

Identical in anatomy with *Chilomonas*, but with two brown or green chromatophores.

Crypt. ovata (?) Ehrbg., Fig. 99, *a, b, c*. Three varieties, possibly different species.

Chlamydomonas Ehrbg.

Spherical to cylindrical, with a delicate shell and prominent chromatophores, which form the chief mass of the body, and contain one or more spherical or ribbon-like pyrenoids. Two flagella, a nucleus, and an eye-spot, and two contractile vacuoles present. Multiplication by division, usually in a resting stage.

Chl. sp. (?), Fig. 116.

Chlorangium Stein.

In the motile condition, spindle-shaped, with two flagella, a delicate shell, and two green, ribbon-shaped chromatophores. Two contractile vacuoles at base of flagellum with a central nucleus, but no eye-spot. In passing into a resting stage it attaches itself by its anterior end and loses its flagella, but secretes a short stalk. While in resting condition, body divides into four parts which burst the shell and secrete stalks, so that a small colony arises.

Chl. sp. (?). Fig. 114 I place with doubt in this genus.

Synura Ehrbg.

Spherical colonies of about fifty radially arranged individuals. Individuals ellipsoidal with a delicate cuticle which is often covered with spines. Two brown chromatophores. Nucleus central and many contractile vacuoles. Eye-spots at the base of the flagellum. The single individuals either united by their hind end or held loosely together by means of the shell.

Sy. uvella Ehrbg., Fig. 104.

Spondylomorum Ehrbg.

Colonies of sixteen individuals which are arranged in four alternating rows. Multiplication by the division of the individuals into sixteen cells. Each individual of the colony bears four flagella.

Sp. quaternarium Ehrbg., Fig. 108. Shown in condition of multiplication at Fig. 108*a*.

Pandorina Ehrbg.

Spherical colonies (thirty-two cells) on the inside of a spherical shell. The individuals are remote from the outer shell, and each bear two flagella.

Eu. elegans (?) Ehrbg., Fig. 109.

ORDER CHOANOFLAGELLATA.

Key to Genera.

1. Solitary 2
   Colonial 3
2. No lorica.................................*Monosiga**
   With lorica...............................*Salpingœca**
3. Individuals inclosed in an irregular jelly...*Protospongia*
   Colonies rotund, or arising in a mass from a funnel-like, open jelly tube..................*Phalansterium*
   Colonies free, of several individuals in an irregular row ....*Hermidium*
   Many individuals on the end of a simple stalk...... *Codonosiga**
   With branched stalk, and single individuals or groups on end of each branch..............*Codonocladium**

Description of Genera.

Monosiga S. K.

Solitary. Attached either directly or by means of a short stalk. Collar expanding in front and changeable in form.

M. ovata Kent, Fig. 106.

Salpingœca J. Cl.

Solitary individual in a lorica which assumes a variety of shapes; generally cup-shaped.

S. Steinii S. K., Fig. 92.

Codonosiga J. Cl.

Similar to *Monosiga,* but forming colonies upon the end of a simple, rather long stalk. Twenty or more individuals unite, forming a spherical group.

C. botrytis Clark, Fig. 107.

Codonocladium Stein.

Body spherical to ovate. The long stalk forming colonies with single individuals on each stalk.

Co. umbellatum Tat., Fig. 102.

ORDER DINOFLAGELLATA.

Key to Genera.

1. Without membrane surrounding the body......... 2
   With membrane surrounding the body........... 3
2. Cross furrow extending only around left side...... *Hemidinium*
   Cross furrow extending wholly around body...... *Gymnodinium**
3. Membrane delicate, structureless, no processes.... *Glenodinium**
   Membrane of polygonal plates; processes, where present, small........................*Peridinium**
   Membrane of plates with long horn-like processes *Ceratium*
   Membrane showing a cross furrow near anterior end, but no processes.....................*Amphidinium*

The genera *Gymnodinium, Glenodinium, and Peridinium* have been found abundantly, but I have, as yet, made no figures of them, and their description is, therefore, reserved for a later publication.

CLASS CILIATA.

Key to Orders.

1. Mouth in a spiral zone of large cilia.............. 3
2. Mouth without a definite spiral zone.............. HOLOTRICHA, p. 39
3. Adoral zone wound to the left; body also uniformly ciliate ....................HETEROTRICHA, p. 53
   Adoral zone wound to the left; ventral surfaces with characteristically arranged large cilia, while the dorsal surface carries only fine cilia or none...... HYPOTRICHA, p. 56
   Adoral zone wound to the right, usually forming an almost complete circle..........PERITRICHA, p. 62

ORDER HOLOTRICHA.

Key to Genera.

1. Solitary 2
   Colonial ....*Maryna*

2. Without shell.................................. 3
With sculptured shell made of numerous pieces: ellipsoidal ....*Coleps**
3. Cilia uniform over body.......................... 4
One or two bands of cilia........................ 25
Cilia only on ventral surface.................... 26
4. With delicate, uniform cilia only................. 5
With tentacle-like processes among the cilia...... *Actinobolus*
5. Mouth without protruding undulating membrane.. 6
Mouth with protruding undulating membrane...... 18
Mouth wanting.......................*Anoplophrya**
6. Mouth terminal or nearly so; no proboscis.......... 7
Mouth somewhat posterior to anterior end, on the ventral surface; sometimes with a proboscis..... 10
7. No evident pharynx.......................... 8
With more or less evident pharynx............... 9
8. Ellipsoidal to ovate.......................*Holophrya**
Like the above, but with a posterior bristle...*Urotricha**
Elongated, cylindrical......................*Chænia**
Elongated, anterior end oblique, neck-like....*Enchelys**
Like the above, but with neck shorter and flattened.. *Spathidium**
Short, purse shaped; mouth covering the whole oblique anterior end......................*Leucophrys*
9. With a long neck, not much flattened, not contractile *New genus*
With a long neck, much flattened......*Trachelophyllum**
With a long neck, not flattened, sometimes telescopic and highly contractile................*Lacrymaria**
Without a neck; body spherical to ovate; pharynx long and evident........................*Prorodon**
10. With proboscis in front of mouth, very flexible..... 11
Without proboscis............................ 14
11. Mouth always open, pharynx rod-like............. 12
Mouth commonly closed, no pharynx............. 13
12. Spherical to ovate, proboscis short, slightly flexible.. *Trachelius**
Long, band-formed, long proboscis, very flexible.... *Dileptus**

13. Much flattened; with broad, clear border, which may be wanting on the right side; with trichocysts.. *Loxophyllum**

Somewhat flattened, but with no hyaline border, and commonly no trichocysts.............. *Amphileptus**

14. Mouth anterior to middle........................ 15

Mouth in middle, or posterior.................... 17

15. Pharynx basket-like; body cylindrical to ovate..*Nassula**

Pharynx not basket-like........................ 16

16. Mouth crescentic; a watch-glass-shaped pigment spot near by; a ciliated lobe in pharynx.....*Ophryoglena**

Mouth surrounded by a furrow extending far backwards ....*Fontonia**

Mouth bearing a few long cilia on its posterior left side; body slightly compressed and ovate....*Colpoda**

17. Mouth near middle; short pharynx; peristome oblique; cilia uniform..................*Paramecium**

Mouth in middle or posterior half of right side; pharynx evident; long cilia behind the mouth.... *Conchopthirus*

18. Peristome not evident; mouth near the front....... 19

Peristome evident.............................. 22

19. Mouth in front of middle....................... 20

Mouth near the middle.......................... 21

20. One undulating membrane; body ovate with anterior end slightly curved to the right; mouth lateral... *Colpidium**

Two undulating membranes, body ovate.....*Glaucoma**

Two undulating membranes, body elongated...*Dallasia**

21. With two membranes; body ovate, slightly compressed, broader behind, and with a long posterior bristle ....*Uronema**

Like *Uronema,* but with an anterior spiral row of long cilia..........................*Dexiotricha**

22. Peristome posterior to middle.................. 23

Peristome not posterior to middle................ 24

23. With an evident membrane; a tuft of long bristles at the posterior end...................*Cinetochilum**

Membrane less evident, and without the long bristles *Microthorax**

24. Peristome covering the whole right side, with a large membrane .... *Lembadion**
Peristomial furrow parallel to the right side; a very large projecting membrane in a depression on the posterior half of peristome............ *Pleuronema**
Like the above but smaller, with a shorter peristome and one or more long posterior bristles... *Cyclidium**
Like Pleuronema but inclosed in a lorica.. *Calyptotricha*
25. With a single row or large cilia........... *Mesodinium**
With two, many-rowed crowns of free cilia.... *Didinium*
With a broad, ring-like band of cilia...... *Urocentrum**
26. Pharynx not basket-like or tube-like.............. 27
Pharynx basket-like or tube-like................ 28
27. With a long neck; body oval ending in a short tail.. *Lionotus**
With the anterior end hook-like and showing an evident peristome and pharynx; brownish..... *Loxodes**
28. Pharynx smooth; small......................... 29
Pharynx basket-like............................ 30
29. Only the anterior end and the right border ciliated.. *Ervilia*
With a middle, swollen, ciliated zone.......... *Trochilia*
30. Body flat.................................... 31
Body not flat.................................. 33
31. Mouth in the anterior half..................... 32
Mouth in the posterior half................ *Opisthodon*
32. Without a movable tail..................... *Chilodon**
With a movable tail......................... *Ægyria*
Body crenate in cross section; without a movable tail *New genus**
33. Body purse-shaped...................... *Phascolodon*
Body ovate; six rows of cilia.............. *New genus**

Description of Genera.

Coleps Ehrbg.

Barrel-shaped, but not always symmetrical; rigid, provided with an armor composed of single plates. The plates, arranged in zones around the body, are almost rectangular, sculptured upon their surface, on the one side

straight, and on the other side indented so as to produce openings through which cilia protrude. The anterior row of plates is toothed; the posterior row triangular, pressed together like a roof. Mouth terminal, surrounded by a row of strong cilia. Pharynx with a longitudinal striated wall, a spherical nucleus, a secondary nucleus, and a subterminal anus.

C. hirtus Ehrbg., Fig. 153.

Anoplophrya Stein.

Mouthless, free swimming, ovate to elongate. Nucleus band-like. Contractile vacuoles well developed. Cilia very long and uniform over the body. The animals are parasites in the intestines of various animals.

An. sp. (?). Fig. 226 represents a species of this genus found freely swimming in a watering trough. Its host being unknown, it is impossible to determine the species.

Holophrya Ehrbg.

Ovate to cylindrical; rounded at both ends. Mouth on the anterior end leading into a slightly developed pharynx. Anus terminal, body striate, with a uniform ciliation.

A large number of minute ciliates have been found belonging apparently to this genus. Their great variability makes the specific determination difficult and uncertain. Figs. 119-123 represent some of these common types, but no attempt has been made, at present, to determine the species. The genus *Holophyra* is in many cases hardly distinguishable from *Enchelys,* since the mouth is sometimes slightly excentric. Fig. 132 represents a spiral ciliate with terminal mouth that is tentatively placed here.

Urotricha Cl. & L.

Like *Holophyra,* except that it possesses a terminal posterior bristle.

U. farcta Cl. & L., Fig. 127.

Balantozoon agile of Stokes, Fig. 130, really belongs to this genus.

Chænia Duj.

Elongated, narrowed in front, contractile. Mouth terminal or sub-terminal, usually closed. No pharynx. Uni-

formly ciliate, but with longer cilia at the anterior end. One terminal contractile vacuole. Nucleus divided into small pieces.

Ch. teres Duj., Fig. 140. This is the only species described, but I have found several other forms that apparently must be classed under this genus. Figs. 138 and 139 represent two of these forms. Fig. 141 is perhaps a small specimen of *Ch. teres.* Fig. 142 represents a very common animal whose relations have appeared doubtful to me. I place them in this genus provisionally, although they may be young forms of some other genus.

Enchelys Ehrbg.

Differing from *Holophyra* chiefly in having an obliquely truncated neck-like prolongation with the mouth slightly on one side. No pharynx, a terminal anus, and a uniform ciliation. Nucleus spherical to ellipsoidal.

Enchelys is another genus that presents great difficulty in specific determination, and is frequently hardly distinguishable from *Holophyra.* Fig. 128 I regard as, perhaps, *En. pupa,* Ehrbg., while Figs. 124, 125, 126, and 134 are, with hesitation, placed in this genus, the evident lateral mouth apparently excluding them from *Holophyra.* More study is required before the limits of these two genera can be drawn.

Spathidium Duj.

Elongated, sac-shaped, flexible, with anterior end narrowed and flattened into a neck which is obliquely truncate. The mouth occupies the whole of the oblique surface and is usually surrounded by lips and closed. Pharynx sometimes with rods. Uniform ciliation, terminal vacuole, nucleus elongated and bead-like.

Spathidium is difficult to distinguish from *Enchelys.* Fig. 128, which I have called *Enchelys,* shows such an elongated neck as to suggest that it may be classed with *Spathidium.* Figs. 129 and 131 are clearly the latter genus.

S. sp. (?), Fig. 129.

S. spathula (?) Duj., Fig. 131.

Prorodon Ehrbg.

Ellipsoidal to ovate, with rounded ends, and occasionally somewhat flattened. The terminal mouth leads into a short or a long pharynx which is covered with a rod-like or a smooth membrane. Anus terminal; one or more contractile vacuoles; nucleus ovate to ribbon-like. Longitudinal striations; uniform ciliation, except that frequently there is a tuft of longer posterior cilia.

Pr. niveus Ehrbg., Fig. 136.

Pr. armatus C. & L., Figs. 137 and 137*a*.

Pr. griseus C. & L., Fig. 144.

The genus *Prorodon* presents wide variations in shape and size. Figs. 136 and 137 represent two extreme types that I have associated with specific names as above shown. Many intermediate forms between these are found.

Trachelophyllum Cl. & L.

Body much flattened, appearing flask-shaped upon the broad side, with an elongated neck-like anterior end. A small retractile proboscis in front, upon which is the mouth leading into a pharynx extending through the neck. Ciliation uniform, with longer cilia around the mouth. Contractile vacuole terminal and many nuclei.

Fig. 156 represents a very large infusorian that does not seem to agree exactly with any described genus. It differs from *Trachelophyllum* in not showing the proboscis, and in having the vacuole divided into many parts. For similar reasons it cannot be placed with *Lacrymaria,* while the other flattened infusorian, *Trachelocera,* is described as being only marine. I therefore place it provisionally with this genus.

Lacrymaria Ehrbg.

Form flask-shaped but changeable; with a short or a long, highly contractile neck, and a rounded posterior end; not flattened; with a plug-like projection carrying the mouth, which is surrounded with a crown of long cilia. Pharynx, a long or short tube frequently longitudinally striped. Body striped longitudinally or spirally; anus terminal or sub-terminal.

L. olor Müll., Fig. 149. Fig 149*a* is the same animal with its neck contracted.

L. sp. (?), Fig. 150, appears to be an undescribed form.

Trachelius Shrank.

Spherical to elliptical; the anterior end with a dorsally projecting proboscis, at whose base is the closed mouth, which leads into an armed pharynx. Contractile vacuoles numerous; nucleus central and commonly single. Ciliation uniform.

Tr. sp. (?). The animal shown in Fig. 148 does not agree with any described form, but it comes nearest to this genus.

Dileptus Duj.

Elongated, slightly compressed, with a long proboscis. Mouth at base of proboscis; pharynx short. Upon the ventral side of the proboscis a row of large cilia extending around the open mouth. Numerous contractile vacuoles along the back. Nucleus ribbon form to bead-like. Striation and ciliation uniform.

D. monilatus Stokes, Fig. 157.

D. gigas C. & L., Fig. 158.

D. sp. (?), Fig. 160.

Loxophyllum Duj.

Flat, leaf-like, with broad hyaline border (sometimes wanting on the left side). Proboscis only slightly developed; mouth on the left, commonly closed. Trichocysts on the right border either scattered or in papilla-like groups. Contractile vacuole posterior, nucleus ribbon or bead-like. Longitudinally striate.

Lox. rostratum Cohn, Fig. 161.

Lox. sp. (?), Fig. 162.

Lox. lamella Ehrbg., Fig. 163.

Lox. sp. (?), Fig. 165.

Amphileptus Ehrbg.

Body elongated, somewhat flattened, prolonged in front into an acute proboscis at whose base lies the mouth, which is commonly closed and not visible. Numerous contractile vacuoles scattered over the surface, or a single terminal vacuole. Nucleus single or double.

Am. gutta Clap., Fig. 143.

Am. sp. (?), Fig. 145.

Nassula Ehrbg.

Ovate to cylindrical; rounded posteriorly. Mouth ventral, about one-third of the way from the anterior end. On the left side, at the top of the mouth, is a depression. From the mouth, extending forward to the left, is a zone of stronger cilia. Pharynx armed with rods straight or curved. Anus terminal. The animals usually contain yellowish, brownish or violet drops, which are derived from the *Oscillaria* which serve as their food.

N. ornata Ehrbg., Fig. 169. Fig. 170 shows the animal in the art of feeding upon a long filiamentous alga.

N. sp. (?), Fig. 164. A much smaller type with more evident trichocysts.

Ophryoglena Ehrbg.

Ellipsoidal, with the posterior end somewhat acute. Ciliation and striation regular. Mouth a third of the distance behind the anterior end, commonly closed, a crescent-shaped or spiral slit, surrounded by a lip and leading into a short pharynx. Upon the left of the mouth is a black homogeneous watch glass-shaped body. One or more contractile vacuoles with well developed vessels. Nucleus single, ellipsoidal or ribbon-shaped, and a spindle-shaped secondary nucleus.

Op. sp. (?), Fig. 221. The placing of this animal in this genus is tentative.

Frontonia Ehrbg.

Ellipsoidal to elongated, somewhat acute behind. Mouth not far from the anterior end, surrounded by elevated ridges which extend backward and gradually vanish. Pharynx short, with rods and two undulating membranes, the left one serving as a grasping organ. Ciliation and striation regular. Nucleus ellipsoidal. One or more secondary nuclei and usually one contractile vacuole. Trichocysts present except in the groove extending from the mouth.

Fr. sp. (?), Fig. 185. This is the largest holotrichous infusorian I have seen, reaching a length of 400-500 μ. It is found somewhat abundantly in New Haven and Middletown.

Fr. sp. (?), Fig. 186. Our most common species.

Fr. sp. (?), Fig. 198. This is a new type of ***Frontonia,*** with a body very much flattened, its dorso-ventral diameter being less than one-third of its lateral diameter. It is abundant in our waters.

Colpoda Müll.

Laterally compressed, with the dorsal surface rounded and the ventral surface straight. Mouth on the ventral surface one-third of the distance back of the anterior end. Upon the posterior edge of the mouth is a number of long cilia. Multiplication by division into four or more parts in an encysted condition.

There is a large number of species of this genus found in our waters. Stokes has described many of them. He divides the genus into two, one of which he names *Tillina;* but this division is not generally accepted. The species described by Stokes that I have found, up to the present time, are in the following list:

C. sp. (?), Fig. 187.

C. campyla, Fig. 188.

C. saprophila, Figs. 189 and 190.

C. sp. (?), Fig. 191.

C. inflata, Fig. 192.

C. sp. (?), Fig. 193.

C. gigas, Figs. 195 and 205.

C. cucullus O. F. Müll., Fig. 196.

Paramecium Müll.

Elongated, slightly flattened. Rounded at both ends or obliquely truncated in front. Mouth in the middle of the ventral surface or further back, in the bottom of a three-cornered peristome depression, extending toward the left side. Anus ventral between the mouth and the end, or terminal. Ciliation regular; nucleus ellipsoidal, central; secondary nuclei, close by, short and spindle-formed. Numerous trichocysts.

Par. caudatum Ehrbg., Fig. 203.

Par. bursaria Ehrbg., Figs. 201 and 202.

Par. trichium Stokes, Fig. 206.

Colpidium Stein.

Similar to *Colpoda,* but less compressed, and with an undulating membrane in front. Mouth oblique, three-cornered. A small peristome a third of the distance from the front. Pharynx short; nucleus spherical, central. Contractile vacuole posterior and dorsal.

C. striatum Stokes, Fig. 176 and Fig. 177.

C. sp. (?), Fig. 183. Referred with doubt to this genus.

C. sp. (?), Fig. 194. A very large form, larger than any described species of *Colpidium.* It may not belong to this genus; but at present I am unable to locate it elsewhere. It is a moderately abundant animal.

Glaucoma Ehrbg.

Somewhat ovate, flattened. Mouth a quarter of the distance from the anterior end, a little to the right; triangular to crescent-shaped, with two undulating membranes. Striation and ciliation regular. Nucleus spherical, central, and a secondary nucleus.

Gl. scintillans Ehrbg., Fig. 182.

Gl. scintillans (?) Ehrbg., Fig. 171.

Fig. 207 represents a common minute infusorian that appears to be *Trichoda pura* (Ehrbg.), which Bütschli places with *Glaucoma.* I can detect no membranes in our specimens, and prefer to retain the name *Trichoda.*

Dallasia Stokes.

Elongated, rounded in front and contracting into a tail behind. One side somewhat flattened, the other convex. Mouth near the front and somewhat triangular, with two membranes much like those of *Glaucoma.* Contractile vacuole single; nucleus single and central.

D. frontonia Stokes, Fig. 175. In the specimens found here the vacuole is posterior instead of anterior as described by Stokes.

Uronema Duj.

Ovate, acute, anteriorly compressed, with the ventral surface straight and the dorsal curved. Mouth in the middle of the ventral surface or somewhat more forward, surrounded by one or more undulating membranes. From the mouth forward extends a furrow in which the

cilia are densely arranged. Pharynx wanting; striation and ciliation regular. On the posterior end a bristle.

U. marinum (?) Duj., Fig. 181, two varieties.

Dexiotricha Stokes.

Similar to the above, but with a spiral row of cilia.

D. plagia Stokes, Fig. 197.

Cinetochilum Perty.

Rigid, flattened, oval, with deeply spiral furrows. Upon the ventral side, beginning at the posterior end, is a peristome slightly widening in front, where the mouth is found, surrounded by an undulating membrane. Ciliation uniform. At the posterior end, upon the right and left, a few long, thread-like cilia. Contractile vacuole posterior, upon the right.

C. margareticum Ehrbg., Fig. 199, ventral and lateral views.

Microthorax Engelm.

Small, nearly oval, the left side straight and the right curved. Ventral surface flat, with two furrows parallel to the right side; dorsal edge curved. Mouth in a flat peristome, posterior, upon the left side, with an undulating membrane on the right. Cilia few, uniform. Nucleus central; contractile vacuole in front of the mouth.

M. sulcatus (?) Ehrbg., Fig. 200, is our common form, but it appears to be smaller than the species *sulcatus*.

Lembadion Perty.

Rigid; oval when seen from the back. Posterior end somewhat acute, anterior end oblique. Ventral surface flat, dorsal convex. A large peristome, which almost covers the whole of the right side of the body, and which carries on its left side an undulating membrane, almost filling the peristome. Striation longitudinal; ciliation uniform, but with a tuft of posterior, longer cilia. Nucleus short, cord-like. One contractile vacuole.

L. bullinum Perty, Fig. 204.

Pleuronema. Duj.

Somewhat oval and flattened dorso-ventrally; both ends rounded; left side more curved than right side. Upon the right side of ventral surface is a large, furrow-

like peristome, from which protrudes a large undulating membrane. Cilia long; striation regular; nucleus spherical, and contractile vacuole terminal. Trichocysts sometimes present.

Cyclidium Ehrbg.

Very similar to *Pleuronema* and frequently united with it. Differs in being smaller, having a shorter peristome and one or more long bristles at posterior end.

Figs. 208 *a, b,* and *c,* represent three types of *Cyclidium,* perhaps *Cy. glaucoma.* Fig. 209 is Stokes' species, *Cy. limetosum.* Figs. 211 to 215 are undetermined species, apparently referable to the genus *Pleuronema.*

Mesodinium Stein.

Small, pear-shaped, with a furrow in the middle; anterior end conical; the mouth at anterior end leads into a long pharynx. Posterior end spherical. In the furrow is a crown of strong cilia, which is occasionally wanting. Four small knob tentacles around the mouth. Nucleus spherical to kidney-shaped, central. Anus and contractile vacuole terminal.

M. sp. (?), Fig. 135. In this specimen the knobs were not seen.

Urocentrum Nitzsch.

Somewhat cylindrical, with a constriction slightly behind the middle. Mouth posterior, surrounded by a flattened area, with a furrow extending backwards; a row of closely arranged cilia, extending as a girdle around the body. A short pharynx. The anterior part of the body uniformly ciliated, with a broad zone of cilia near the middle and posterior end. A prominent tuft of fused cilia at posterior extremity. Nucleus worm-shaped, in the hinder part of the body, with round, secondary nuclei. Anus and contractile vacuole terminal.

Ur. turbo Müll., Fig. 210.

Lionotus Wrz.

Elongated, with a flattened, ciliated, ventral (right side) surface, and a convex, dorsal (left side) surface; commonly with an evident proboscis, which is hyaline, as is also the short caudal extremity. On the left side of pro-

boscis a row of long cilia with trichocysts. Mouth a long slit, upon left side at base of proboscis, commonly not visible. Usually two nuclei and a contractile vacuole at beginning of the tail, near the dorsally opening anus.

L. wrzesniowskii Kent, Fig. 155.

L. sp. (?), Fig. 146.

L. fasciola Ehrbg., Fig. 147.

Fig. 133 represents a form which I have provisionally placed with this genus.

New Genus (?).

Body elongated and uniformly ciliate, with a proboscis resembling *Lionotus*. The mouth, however, is terminal, and leads into a pharynx armed with rods. Nucleus double, and several contractile vacuoles.

Fig. 159. Only a single specimen of this peculiar form has been found.

Loxodes Ehrbg.

Inflexible, flattened, elongated, and leaf-like, the anterior end hook-like and bent to left. Ventral surface flat, with ciliated ribs, dorsal surface smooth, curved, and without cilia. The edge of the body with somewhat longer cilia. Mouth on the left anterior edge, at the bottom of a slit-like peristome and leading into an evident pharynx. Many nuclei and secondary nuclei. Contractile vacuoles uncertain.

Lox. rostrum Müll., Fig. 154.

Chilodon Ehrbg.

Much compressed, with a flat or slightly hollowed ventral surface, and a convex dorsal surface. A thin, flexible hyaline border prolonged in front into a projection directed forward and to the left. Mouth in the middle of the body, with a basket-like pharynx of ten to sixteen rods; its inner end frequently spirally rolled. Ventral surface regularly striated and ciliated. Dorsal surface without cilia. A band of stronger cilia extending from the mouth to the end of the elongated projection. Nucleus ellipsoidal, of peculiar structure. One or more contractile vacuoles.

Ch. cucullulus Müll., Fig. 174.

Ch. vorax Stokes, Fig. 180.
Ch. caudatus Stokes, Figs. 166 and 173.†
Ch. megalotrocha Stokes, Fig. 168. An extremely common species in infusions.
Ch. sp. (?), Fig. 172.

New Genus (?).

Body nearly spherical in outline, with a slight lip at anterior end, at bottom of which is found a mouth. Six prominent rows of cilia on ventral surface, extending from pole to pole. Nucleus and contractile vacuole present, posterior. Motions slow. No evident pharynx.

Fig. 184. This peculiar animal has been found several times in our water. It cannot be placed in any genus known to me.

ORDER HETEROTRICHA.

Key to Genera.

1. With undulating membrane 2
   Without undulating membrane 3
2. Flattened; narrowed in front, peristome long, on left *Blepharisma**
   Cylindrical or purse-shaped; not flattened; peristome short, inclosing the wide anterior end.. *Condylostoma**
   Body more or less spiral; peristome furrow-shaped.. *Metopus**
3. Membranellæ evident and somewhat spiral......... 4
   Membranellæ not spiral, feather-like; body in a lorica 5
4. Long, thread-shaped, or somewhat flattened...... *Spirostomum**
   Purse-shaped; oblique in front, peristome funnel-shaped, sunken in the body.............. *Bursaria**
   Purse-shaped; peristome flat, inclosing whole anterior end of body.................. *Climacostomum*
   Purse-shaped; peristome broad in front but not inclosing whole anterior end of the body, extending obliquely to the right.................. *Balantidium*

† This is *Chilodon caudatus* of Stokes, but should perhaps more properly be placed under the generic name *Ægyria* because of its caudal appendage. *Ægyria* is said to contain one species only and to be found only in salt water, and that species is certainly not the one described above.

Body funnel-shaped to ovate, peristome inclosing anterior end and surrounded by ciliated zone...*Stentor**

5. Lorica tubular, gelatinous................*Tintinnidium*

Lorica various, chitinous...................*Tintinnus*

Description of Genera.

Blepharisma Perty.

Much flattened; anterior end acute, somewhat hook-like, and bent to the left. Peristome a deep furrow close to the left-hand border in front, and extending to the middle of the body, where is found a short, slightly bent pharynx. On left wall of peristome is a row of strong membranellæ, but upon its right side an undulating membrane. Body spirally striate.

Bl. sp. (?), Fig. 216.

Bl. undulans (?), Fig. 217.

Bl. ovata (*Apgaria* of Stokes), Fig. 218.

Bl. sp. (?), Fig. 228.

Condylostoma Duj.

Sometimes contractile, sometimes not, with a body either elongated or rounded. Peristome extending one-third of the distance behind the anterior end. Mouth broad, pharynx slightly developed. An evident undulating membrane on right side of peristome. Nucleus bead-like on the right side. Contractile vacuole and anus terminal.

Con. sp. (?), Fig. 220. The identification of this animal is doubtful.

Metopus Cl. & L.

Cylindrical, somewhat acute at both ends. Peristome a long furrow extending from the left anterior end, in a spiral direction, to the mouth, which lies near the middle of the ventral side. Pharynx short. Anterior end of body bent toward the ventral surface and toward the left so that the anterior portion of the peristome is covered. On left side of peristome is a row of membranellæ. On right side an undulating membrane. Striations regular; ciliation uniform, but with a tuft of longer cilia on the anterior and posterior ends. Nucleus cylindrical, with a

secondary nucleus. Anus and contractile vacuole terminal. Body very contractile, assuming a variety of forms, as shown in Figs. 223, 224, and 225, which may, however, be regarded as separate species.

M. sigmoides Cl. & L., Figs. 223-225.

Spirostomum Ehrbg.

Very contractile, elongated, cylindrical or thread-formed. Peristome a long furrow reaching to the middle of the body and leading into a short pharynx. Strong membranellæ on the left side of the peristome, but no undulating membrane. Striation spiral. Nucleus ellipsoidal or bead-like. Anus terminal; a contractile vacuole extending almost to the anterior end.

Sp. teres Cl. & L., Fig. 222.

Sp. ambiguum Ehrbg., has also been found, but no figure of it is given.

Bursaria O. F. Müll.

Inflexible, somewhat purse-shaped. In front obliquely truncate. Behind broadly rounded. Ventral surface flat. Dorsal surface convex. Peristome extending from the anterior backwards into a deep funnel, which opens on the ventral side by a slit reaching as far as the middle of the body, and passing imperceptibly into a pharynx-like tube. Adoral zone on the left side of the peristome composed of small membranellæ. Striations regular; nucleus long and ribbon-like and many secondary nuclei. Many small contractile vacuoles and a terminal anus.

B. truncatella Müll, Fig. 231.

Stentor Ehrbg.

Fixed, or free swimming. When attached the body is elongated and trumpet-formed, with a more slender posterior end, sometimes inclosed in a jelly-like lorica. When free swimming, pear-shaped to ovate. A spiral row of strong cilia extending around the truncated anterior end, beginning on the ventral side with an inwardly projecting curve, and extending from there over the right dorsal and left side again to the ventral side, where it ends in a mouth leading into a short pharynx. Striations evident; ciliation fine and regular; nucleus ellipsoidal, thread-formed or

bead-like. Many small secondary nuclei. Anus near the left end of the adoral spiral. The contractile vacuole, lying in the same region, has a long canal reaching to the posterior end of the body.

S. cæruleus (?) Ehrbg., Fig. 240.

S. polymorphus Ehrbg., Fig. 246. Fig. 245 represents the same species, possibly. The species is highly variable. Fig. 245 shows the animal in process of division.

Balantidium Cl. & L.

This is a parasitic genus. Fig 219 found free swimming is provisionally referred to this genus. Possibly *Bal. coli.*

ORDER HYPOTRICHA.

Key to Genera.

1. Body flattened.................................. 2
   Body not flattened.............................. 13
2. Cilia bristle-like, in groups...................... 3
   Ventral side uniformly ciliate except sternum; a group of stronger cilia behind peristome and near posterior end........................*Trichogaster*
3. Many border cilia................................ 4
   Few or no border cilia........................... 12
4. Ventral cilia many, in rows....................... 5
   Ventral cilia few, rows not evident............... 10
5. Ventral cilia all bristle-like, two or more rows...... 6
   Ventral cilia style-like, sometimes with two additional rows of cilia parallel to right border, or with three such rows of which the inner has only a few cilia.................................. 9
6. Five or more longitudinal rows of ventral cilia; peristome on ventral surface................*Urostyla**
   Five nearly straight rows of ventral cilia; peristome lateral ....*New genus**
   Six oblique rows of ventral cilia; body kidney-shaped *Kerona*
   Two or three rows of oblique cilia; body elongated in front into a neck...................*Stichotricha**
   Two rows of ventral cilia; body not elongated in front 7

One row of about seven large ventral cilia; no sternal cilia and with long border and anal cilia....*Belladina*

7. Body flask-shaped....................*Platytrichotus**

Body not flask-shaped.......................... 8

8. With no sternal cilia....................*Holosticha**

With five sternal cilia and fifteen to seventeen anal cilia upon the left side..................*Amphisia*

With three sternal and no anal cilia; body narrowed behind ....*Uroleptus**

With the two rows of ventral cilia wide apart, and no sternal cilia........................*Psilotricha*

9. Five ventral cilia and two or three rows of bristle-like cilia on either side, of which the inner rows have only a few cilia................*Pleurotricha**

Three of four oblique rows of cilia, and three rows parallel to the peristome border......*Onychodromus**

One somewhat irregular oblique row of bristle-like cilia and five or six sternal cilia..........*Gastrostyla*

10. Peristome wholly lateral, very small; usually two ventral cilia in front and five anal cilia..*Gonostonum*

Eight ventral cilia and five anal cilia at the base of the tail..............................*Urosoma**

Five ventral cilia.............................. 11

11. Inner wall of peristome bent toward outer wall; without caudal bristles; body usually flexible.... *Oxytricha**

Inner wall of peristome bent toward the outer wall; without caudal bristles; body not flexible....*Histrio**

Inner wall of peristome bent away from outer wall; usually with three caudal bristles.......*Stylonychia**

12. Four border cilia at posterior end; adoral zone surrounding the front.....................*Aspidisca**

No border cilia; adoral zone confined to the left side *Euplotes**

13. Bearing outside the adoral zone, near the middle, a simple or double crown of long bristles.....*Halteria**

Like the above but without the crown of bristles.... *Strombidium**

Urostyla Ehrbg.

Elliptical to ovate, both ends rounded. Ventral surface flat, dorsal surface curved; body flexible. Three or more bristle-like sternal cilia and five or more longitudinal rows of ventral cilia, those on the sternum especially developed, while those on the rest of the body are smaller. Commonly five to twelve anal cilia in an oblique row, extending to the left. Peristome an elongated triangle with an undulating membrane. Two or more nuclei.

U. trichota (*Hemiclostyla* of Stokes), Fig. 237.

U. vernalis (?) Stokes, Fig. 239.

U. trichogastra Stokes, Fig. 241. Perhaps all of these are only varieties of *U. grandis* Ehrbg.

New Genus

Elongate, rounded at both extremities, not flexible. Peristome on the right hand margin and extending back of the middle, marked by a row of long cilia or membranellæ, that bends to the left to lead to the mouth. Besides border cilia there are four oblique rows of cilia upon the ventral surface. Nuclei, four in number; contratile vacuole single.

The interesting animal shown in Fig. 279 does not agree with any described genus. Two specimens have been found.

Stichotricha Perty.

Elongated, narrowed in front, rounded behind, with a body nearly cylindrical and very contractile. Peristome narrow, upon the left side, extending to the middle or even back of it. Membranellæ long, the two or three anterior ones extending over the front end of the body as bristles. The border cilia extend uninterruptedly around the posterior end. Sternal and anal cilia wanting.

St. secunda Perty, Fig. 236.

Uroleptus Ehrbg.

Sometimes contractile, sometimes not; elongated, narrow, cylindrical or flattened. Anterior end rounded, posterior end prolonged into a caudal projection. Three sternal cilia, two rows of ventral cilia, but no anal cilia. The border cilia pushed on to the ventral surface. Peristome about one-third the length of the body.

U. longicaudatus Stokes, Fig. 232.

U. musculus Ehrbg., Fig. 233.

U. musculus (?), Fig. 234.

U. dispar Stokes, Fig. 243.

Platytrichotus Stokes.

Like *Uroleptus,* but body flask-shaped. Frontal styles five; two rows of ventral cilia, and no anal cilia. Border cilia uninterrupted.

Pl. opisthobolus Stokes, Fig. 238.

Pleurotricha Stein.

Not contractile, rounded at both ends; somewhat oval in outline, with eight sternal cilia. Ventral cilia arranged in two rows; five anal cilia, of which the two on the right side are near the end of the body. Border cilia an unbroken row. Between the border cilia and the ventral cilia, upon one or both sides, are one to three accessory rows of bristle-like cilia. Upper lip developed; peristome broad, one-third the length of the body.

Pl. sp. (?), Fig. 235.

Onychodromus Stein.

Not flexible. In outline somewhat rectangular, with slightly rounded ends. Ventral surface flat, dorsal surface convex. Peristome broad, three-angled, reaching to the middle of the body. Upper lip present. On the right anterior end three strong cilia behind which are three rows of cilia parallel with the right edge of the peristome. Three or four oblique rows of ventral cilia, running from right to left; five or six strong anal cilia; border cilia uninterrupted. Upon the dorsal surface two processes. Four to eight nuclei and one contractile vacuole.

On. grandis Stein, Fig. 247.

Urosoma Kow.

Similar to *Oxytricha,* but with eight ventral cilia. Posterior extremity prolonged, with five to eight cilia at the beginning of the prolongation.

U. cienkowski Kow., Fig. 248. This is provisionally referred to this genus. Only one specimen yet found.

Oxytricha Ehrbg. (Stein, Sterki).

Narrow elliptical, rounded at both ends. Ventral sur-

face flat, dorsal surface convex; flexible. Right border of the peristome bending toward the left. Eight sternal cilia; five ventral and five anal cilia. Without caudal appendages; border cilia often crowded on to the ventral surface.

Ox. pellionella Müll., Fig. 249.
Ox. bifaria Stokes, Figs. 250, 256, and 257.
Ox. fallax Stein, Fig. 251.
Ox. parvistyla Stein, Figs. 252 and 253.
Ox. hymenostoma Stokes, Fig. 254.
Ox. sp. (?), Fig. 255.
Ox. agilis Stokes, Fig. 260.
Ox. sp. (?), Fig. 261.

Holosticha Wrz.

This genus is frequently united with *Oxytricha*, but is here separated by the absence of the regular eight sternal cilia and the presence of two uninterrupted rows of ventral cilia.

H. sp. (?), Fig. 242.
H. vernalis Stokes, Fig. 244.
H. setigera (?), Fig. 265.

Histrio Sterki.

Inflexible, similar to *Stylonychia,* but with a narrower peristome, which has its right border turning somewhat toward the left. The caudal bristles are wanting.

H. sp. (?), Fig. 262.
H. erethisticus Stokes, Fig. 263.
H. complanatus Stokes, Fig. 264.

Stylonychia Ehrbg.

Inflexible, rarely flexible, with flat ventral and convex dorsal surface. Peristome broadly three-angled, reaching to the middle of the body, or shorter; its right border not bent toward the left. Eight sternal, five ventral and five anal cilia arranged as in *Oxytricha.* The middle of the three sternal cilia is immediately behind the right edge of the upper lip. Commonly three large caudal bristles interrupting the border cilia.

St. pustulata Ehrbg., Fig. 258. Not exactly like the described species. Fig. 266.

St. notophora Stokes, Fig. 259.
St. sp. (?), Fig. 267. Perhaps a variety of *St. mytilis.*
St. putrina Stokes, Fig. 269.
St. mytilus Müll., Fig. 273.
St. fissieta C. & L., Fig. 282.

Euplotes Ehrbg. (Stein).

Armored, inflexible, round to oval outline, with ventral surface flat, and dorsal surface convex; ribbed. Peristome large, broad, three-angled, reaching the middle of the body or still further back. The right edge of the peristome slightly drawn out to partly cover the peristome. Nine or ten large cilia upon the sternum; five large anal cilia and four border cilia, two of which are usually at the hind end and two at the posterior left lateral border. Nucleus ribbon-like on the left side, bending in front and behind toward the right. Secondary nuclei near the left front end of the nucleus. Contractile vacuole on the right border.

Eu. sp. (?), Fig. 268.
Eu. carinata Stokes, Fig. 270.
Eu. plumipes Stokes, Fig. 271.
Eu. charon Müll., Fig. 272.

Aspidisca Ehrbg.

Inflexible, round or short oval in outline. Left side slightly and right side strongly curved; ventral side flat, dorsal side convex. Right border thickened. Adoral zone not extending around the anterior end, but reaching backward beyond the middle of the body. The right border of the peristome extends over the peristome so that it is open only by a narrow opening on the left side. Anterior border with a bay-like depression, or sometimes drawn out into a hook-like process. Hind end of the peristome border with one or more teeth from which a transverse channel extends over the ventral surface in front of the anus. Seven scattered ventral cilia, and commonly five anal cilia. Nucleus thread-like, sometimes describing a complete circle. Contractile vacuole simple.

Asp. costata Duj., Fig. 281.
Asp. sp. (?), Fig. 280.

Halteria Duj.

Inflexible, spherical. Upon the anterior end an adoral ciliated zone which extends from the right over the dorsal surface to the left, and then leads to a ventral mouth. The part of the body surrounded by the spiral zone slightly protruding. Near the middle of the body is a crown of simple long bristles, but otherwise it is without body cilia. Spherical nucleus; contractile vacuole near the left side.

H. grandinella Müll., Fig. 227. Fig. 227a shows the same species in process of division. Another view of probably the same animal is shown in Fig. 230.

Strombidium Cl. & L.

Like *Halteria,* but without the bristles. The part of the body surrounded by the ciliated zone is protrusible; frequently with trichocysts. Upon the ventral surface a few single cilia or groups of cilia; colorless or yellowish; nucleus and contractile vacuole as in *Halteria.*

Str. sp. (?), Fig. 229.

ORDER PERITRICHA.

Key to Genera.

1. No lorica.................................. 2
   With lorica 8
2. No stalk.................................... 3
   With stalk; simple or branched, with or without an axial fibre.................................. 5
3. Posterior ciliated ring persistent; the disk-shaped posterior end with a chitinous ring......*Trichodina**
   Posterior ciliated ring found only in the swimming stage 4
   Posterior ciliated ring wholly absent; never attached; posterior end with two bristles....*Astylozoön*
4. Posterior end elongated; usually attached......*Scyphidia*
   Posterior end not elongated; body conical; attached or free; when contracted acorn-shaped........*Gerda*
5. Stalk branched.............................. 6
   Stalk simple................................ 7
6. Stalk retractile; each zooid contracting separately.. *Carchesium**

Stalk retractile; all zooids contracting together.... *Zoöthamnium**
Stalk not retractile; peristomial disk broad....*Epistylis**
Stalk not retractile; peristomial disk long-stalked.. *Opercularia**

7. Stalk retractile............................*Vorticella**
Stalk not retractile; without an operculum..*Rhabdostyla**
Stalk not retractile; with operculum........*Pyxidium**

8. Lorica gelatinous ....*Ophrydium*
Lorica chitinous 9

9. Cylindrical to ovate, unstalked or with a short cylindrical stalk ....*Cothurnia*
Ovate, cup-shaped or flattened, with an ear-shaped projection bearing the mouth; a short, thick ringed stalk ....*Cothurniopsis*
Flattened, with the whole of one side attached to the support; animal attached to the lorica by a stalk-like outgrowth ....*Vaginicola*
Flattened, with posterior flattened end attached to the support; with the peristome process attached to the edge of the mouth..............*Lagenophrys*

Description of Genera.

Trichodina Ehrbg.

Solitary, short, cylindrical or barrel-form, with a posterior row of cilia, over which lies a ring-like fold running around the body. The circular flat base with which the animal attaches itself forms a sucker. It is covered by a chitinous membrane whose peripheral zone is radially striated. Adoral zone extends spirally around the flattened anterior end. Nucleus ribbon-shaped and one contractile vacuole. Animals all parasitic.

P. pediculus Ehrbg., Fig. 301. On *Hydra.*

Vorticella Linn.

Body bell-formed, with a more or less evident, outwardly extending peristome; cuticle often ringed. With a contractile stalk, frequently longer than the body, by which the animal is attached. Adoral zone describing more than a circle. Nucleus simple, ribbon or horse-shoe

shape. Secondary nucleus near the primary nucleus. One contractile vacuole. The animals frequently live in companies but are never colonial.

Figs. 274-277, 283-286, 291-294, 296 and 298 represent a number of separate types of *Vorticella* found in our waters. It is difficult to arrange them satisfactorily into species, and no attempt will be made in the present paper to attach specific names to the forms described.

Rhabdostyla S. K.

Solitary, upon a short, not contractile stalk. In other respects like *Epistylis*.

R. brevipes Cl. & L., Fig. 278.

R. sp. (?), Fig. 295.

Pyxidium S. K.

Solitary, with a short stalk; in other respects agreeing with *Opercularia*.

P. ramosa Stokes, Fig. 290.

Epistylis Ehrbg.

Colonial, the single individuals of the colony standing about the same height. With a stiff branched stalk containing a canal, but no muscles; hence, not contractile. Animals narrow to broad bell form, mostly with a ringed cuticle.

E. flavicans Ehrbg., Figs. 287, 288, 289. The last figure shows that the spiral band makes four circles around the disk.

Carchesium Ehrbg.

Forming richly branched colonies in which the stalk muscles of the single individual are not attached, but end abruptly at the base of the individual stalks, enabling the individuals to contract independently. Animals all alike in size and structure. Ciliated spiral forming about one and a half circles. Nucleus horse-shoe shape, with a small secondary nucleus near by. One contractile vacuole.

C. polypinum Linn., Fig. 299.

Zoöthamnium Ehrbg.

Much like *Carchesium*, but with a common muscle in the stalk, causing all individuals of the colony to contract together.

One species of *Zoöthamnium* has been found, but no figure of it has yet been made.

Opercularia Stein.

Colonial, with stiff branched stalks which are often ringed. Animals not bell-shaped, but ellipsoidal to ovate, with a peristome not expanded. The ciliary disk upon a long, thin stalk, around which a vestibule extends on either side, closing like a lid. Nucleus short or ribbon-like. One contractile vacuole.

Op. sp. (?), Fig. 297 *a, b, c.*

CLASS SUCTORIA.

Key to Genera.

1. Tentacles simple.............................. 2
   Tentacles branched; not retractile.......*Dendrocometes*
2. No shell 3
   With shell 6
3. No stalk 4
   Stalked, tentacles on all sides or in bundles..*Podophrya**
4. Solitary 5
   Colonial, base branched with branching offsets whose swollen ends constitute the individuals...*Dendrosoma*
5. Spherical; tentacles on all sides.........*Sphærophrya**
   Irregular, fixed by a broad base; tentacles in bundles *Trichophrya*
   With a single movable anterior process instead of tentacles; parasitic on *Cyclops*..............*Rhyncheta*
6. Shell unstalked, posterior end prolonged into a projection; attached to *Epistylis;* two to five long movable tentacles ....*Urnula*
   Unstalked; disk-formed, tentacles in bundles...... *Solenophrya*
   Stalked, frequently enclosed by lobes in front....*Acineta*

Description of Genera.

Sphærophrya Cl. & L.

Without stalk; somewhat spherical, covered with knobbed tentacles. Nucleus round or ellopsoidal. One contractile vacuole.

S. magna Maup., Fig. 303.

Podophrya Ehrbg.

Spherical to pear or club-shaped, upon a stalk. Tentacles usually knobbed, either in groups or scattered over the surface. Nucleus simple with a secondary nucleus. One or more contractile vacuoles. In some species the animals may become detached from the stalk and live in a free condition.

P. sp. (?), Figs. 300, 302.

Index.

PLATE I; FIGS. 1 TO 9; ALL MAGNIFIED 500 DIAMETERS.

PLATE I.

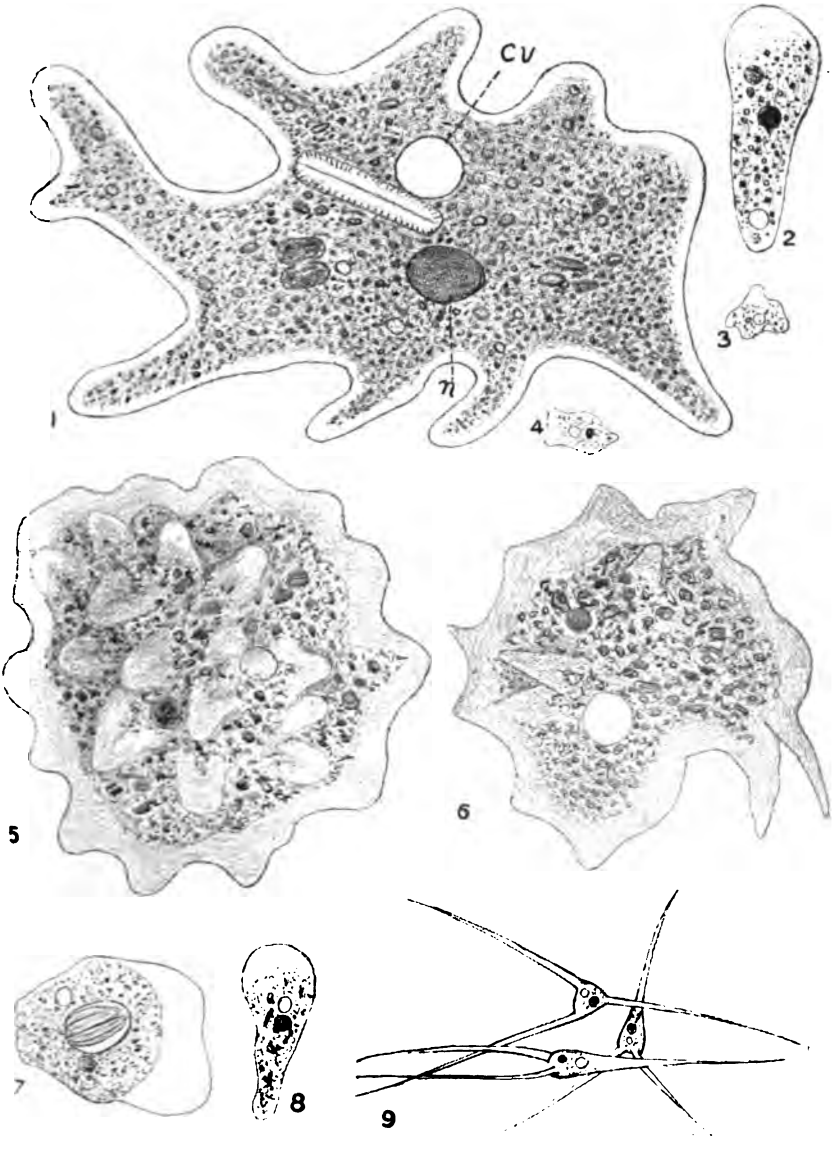
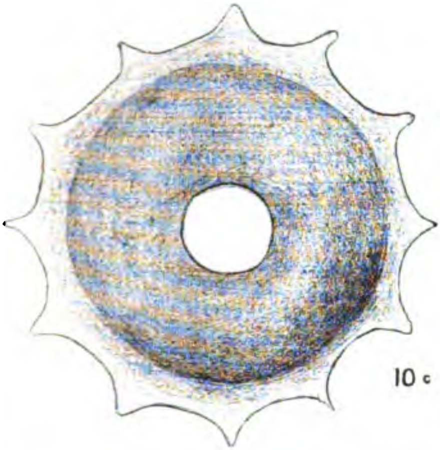
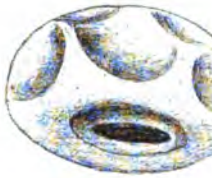


Plate II; Figs. 10 to 16; All Magnified 500 Diameters.

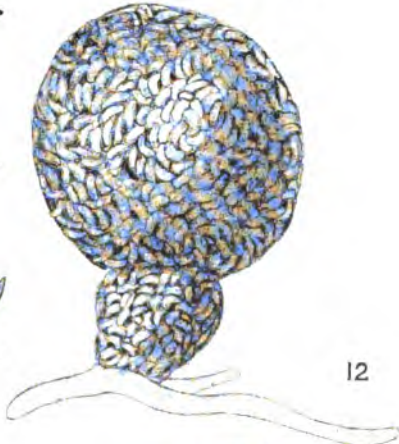
PLATE II.



10 c

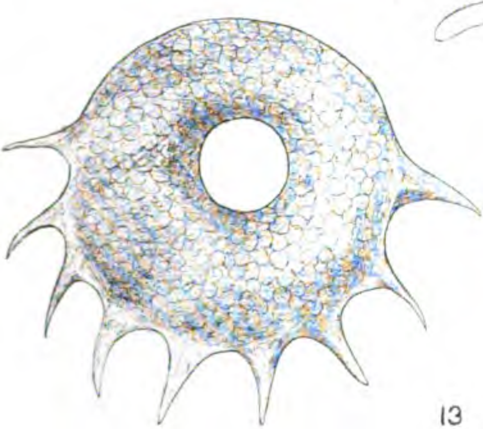


11

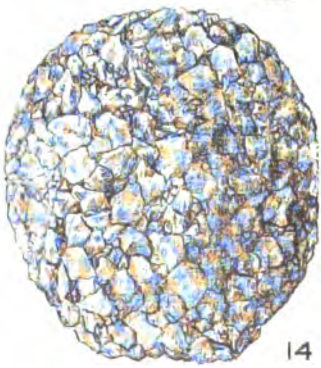


12

10 a

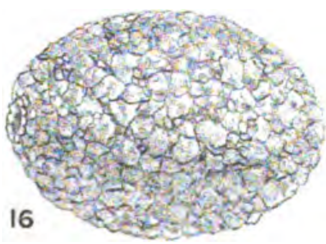


13



14

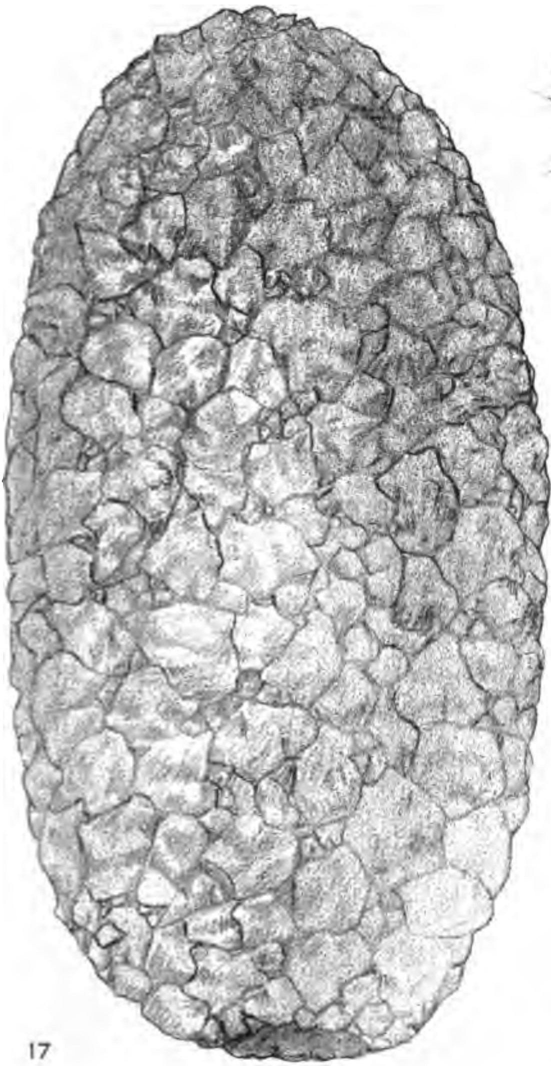
15



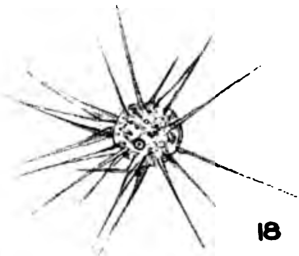
16

PLATE III; FIGS. 17 TO 21; ALL MAGNIFIED 500 DIAMETERS.

PLATE III.

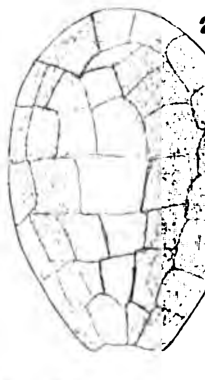


17



18

19



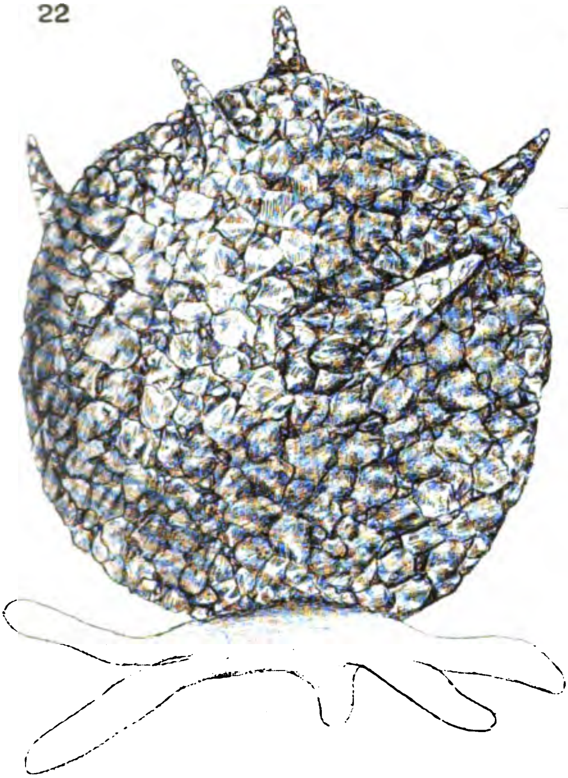
20

21

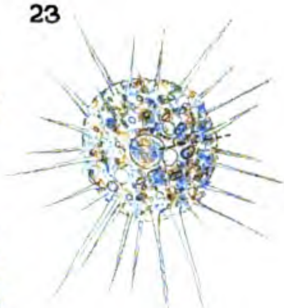
PLATE IV: FIGS. 22 TO 26: ALL MAGNIFIED 500 DIAMETERS.

PLATE IV.

22

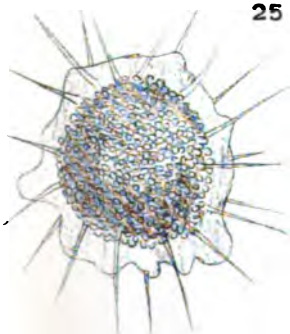


23



24

25



26

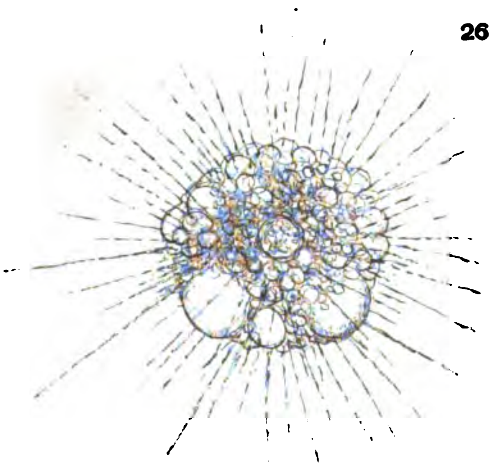
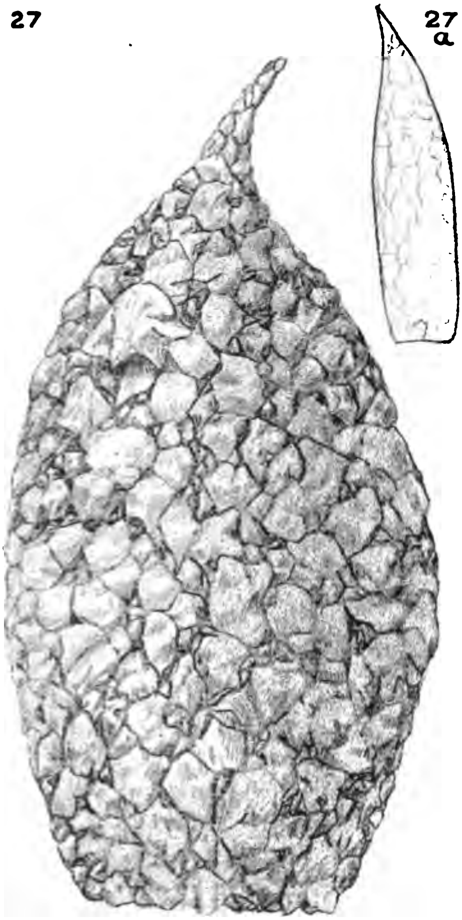


PLATE V; FIGS. 27 TO 31; ALL MAGNIFIED 500 DIAMETERS.

PLATE V.

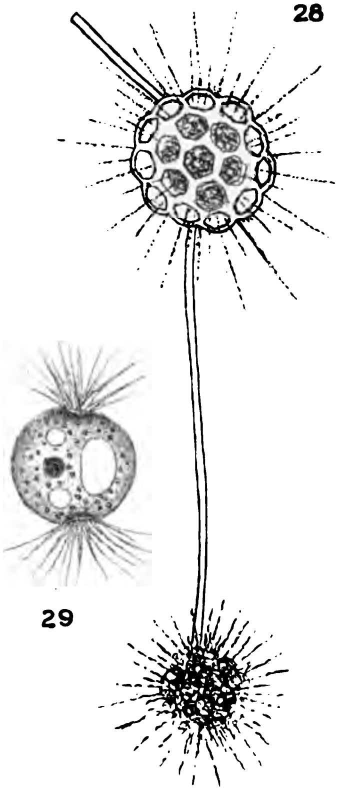
27

27 a

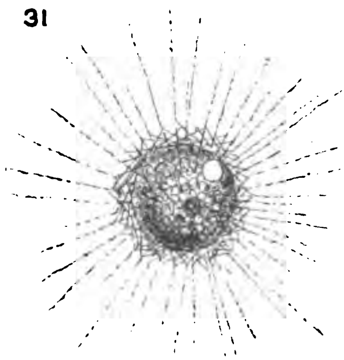


28

29



31



30

PLATE VI; FIGS. 32 TO 49; MAGNIFIED 1000 DIAMETERS.

PLATE VI.

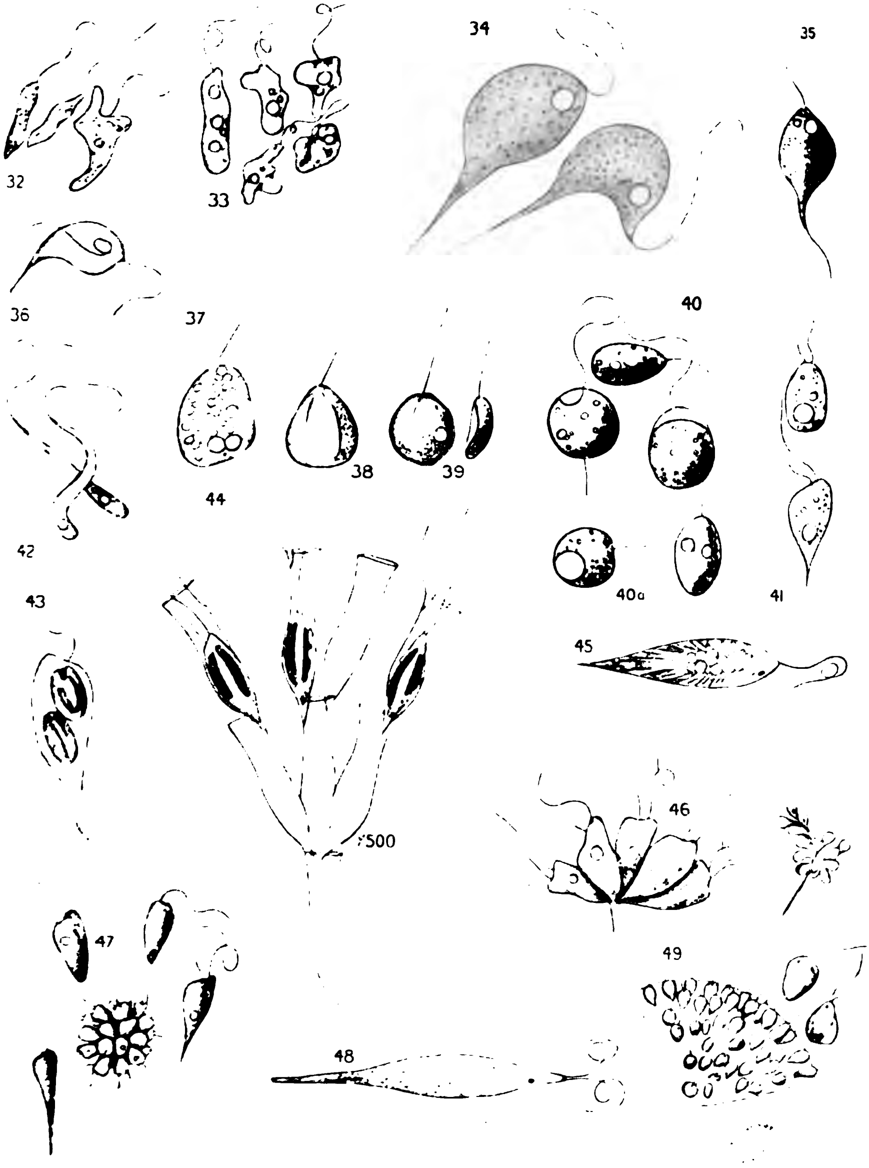


Plate VII; Figs. 50 to 71; Magnified 1000 Diameters.

PLATE VII.

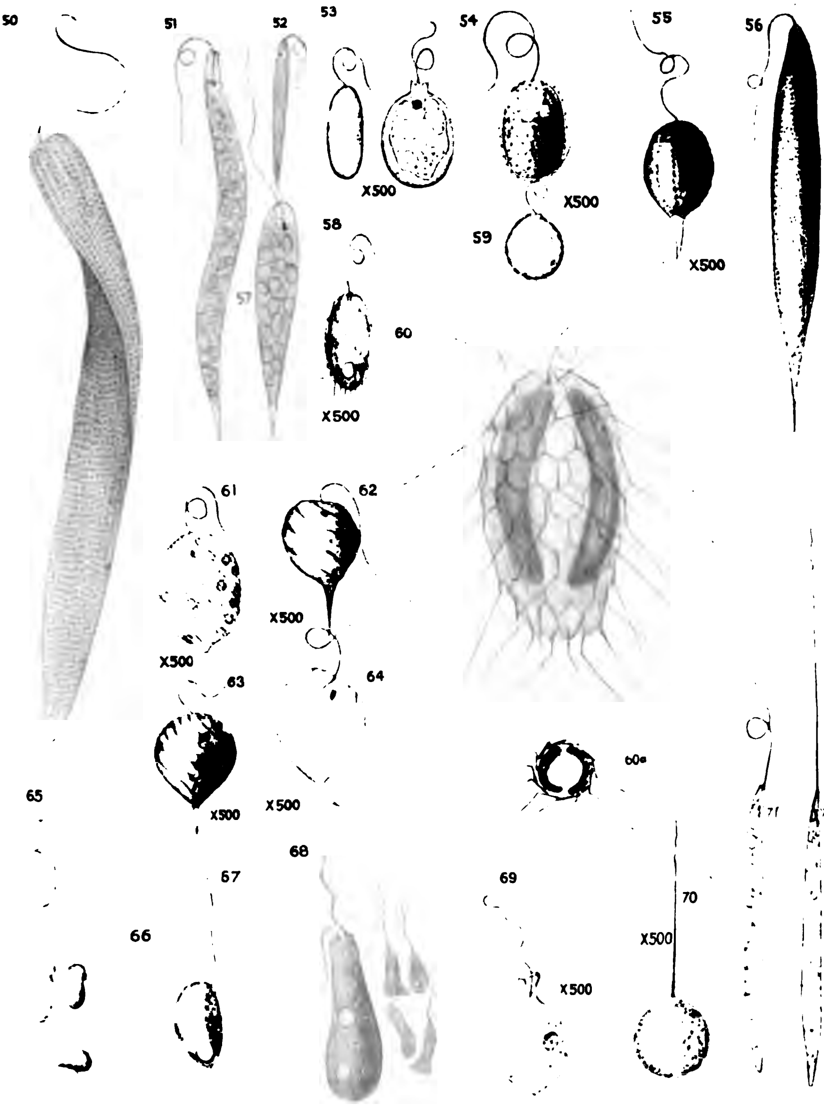

50
51
52
53
X500
54
X500
55
X500
56
57
58
59
60
X500
61
X500
62
X500
63
X500
64
X500
60a
65
66
67
68
69
X500
70
X500
71
71a

PLATE VIII; FIGS. 72 TO 96; MAGNIFIED 1000 DIAMETERS.

Fig. 72. *Peranema trichophora* (?) The figures at the right show the peculiar motions of the body, all of the contortions shown following each other in a few seconds. . p. 28
Fig. 73. *Astasia* sp. (?) . . . . p. 29
Fig. 74. *Peranema trichophora* Ehr . . . . p. 28
Fig. 75. *Anisonema* sp. (?) . . . . p. 31
Fig. 76. *Anisonema obliqua* (?) Stokes . . . . p. 31
Fig. 77. *Heteromita* (*Bodo*) *ovata* Stokes . . . . . . p. 30
Fig. 78. *Heteromita* sp. (?) . . . . p. 30
Fig. 79. *Heteromita globosa* Stokes . . . . p. 30
Fig. 80. *Anisonema acinus* Duj . . . . p. 31
Fig. 81. *Metanema* sp. (?) . . . . p. 31
Figs. 82 to 85. *Heteromita variabilis* Stokes . . . . . . p. 30
Fig. 86. *Heteromita acus* Stokes . . . . p. 30
Fig. 87. *Atractonema tortuosa* Stokes . . . . p. 28
Fig. 88. *Clostonema socialis* Stokes . . . . p. 29
Fig. 89. *Entosiphon sulcatus* Duj . . . . p. 32
Fig. 90. *Clostonema socialis* (?) Stokes . . . . p. 29
Fig. 91. *Chilomonas paramecium* Ehr . . . . p. 35
Fig. 92. *Salpingœca steinii* S. K . . . . p. 38
Fig. 93. *Cryptoglena pigra* Ehr . . . . p. 26
Fig. 94. *Heteronema globiformis* (?) Ehr. 94*a* a side view . . . . p. 32
Fig. 95. *Chilomonas* sp. (?) . . . . p. 35
Fig. 96. *Bodo globosus* Duj. Perhaps the same as Fig. 79 . . . . p. 30
Fig. 97. *Hexamitus inflatus* Duj . . . . p. 36
Fig. 98. *Hexamitus inflatus* . . . . p. 36
Fig. 99. *Cryptomonas ovata* Eher. *a*, *b*, and *c* different varieties . . . . p. 36
Fig. 100. *Elvirea cionæ* Parona . . . . p. 31

PLATE VIII.

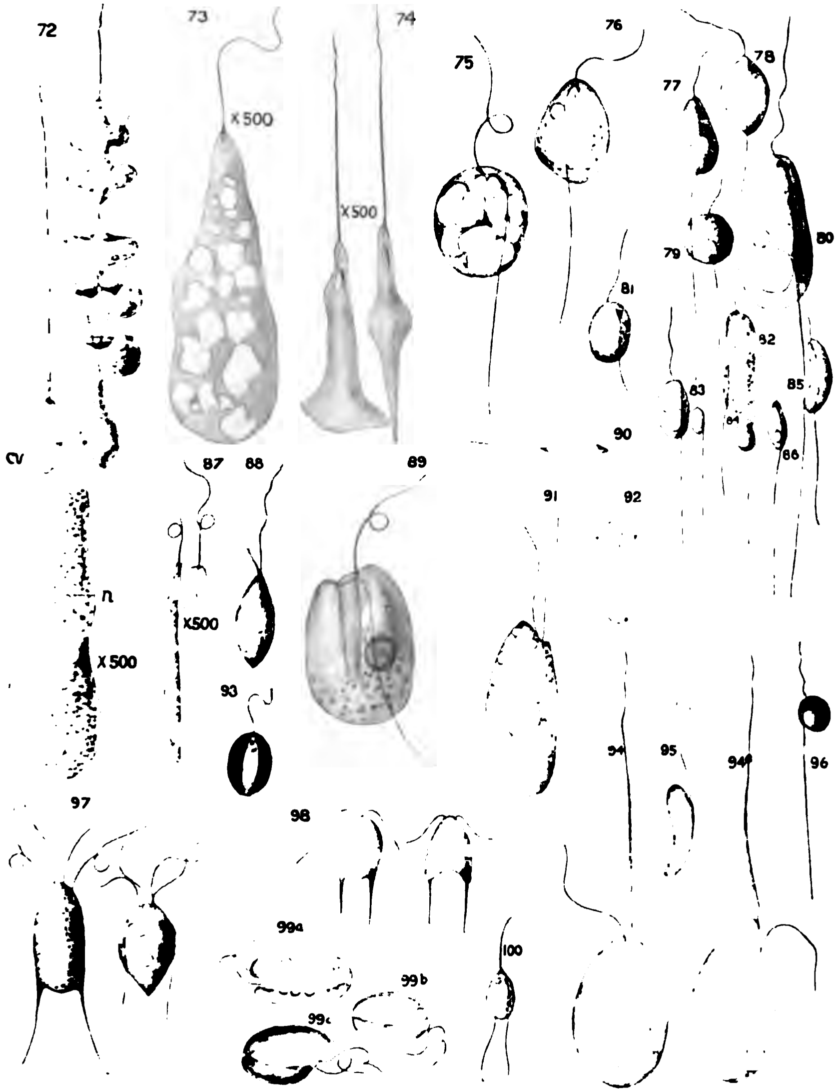

72
73
×500
74
×500
75
76
77
78
79
80
81
82
83
84
85
86
90
cv
87
88
89
×500
n
×500
91
92
93
94
95
94a
96
97
98
99a
99b
99c
100

PLATE IX; FIGS. 101 TO 118; MAGNIFIED 1000 DIAMETERS.

PLATE IX.

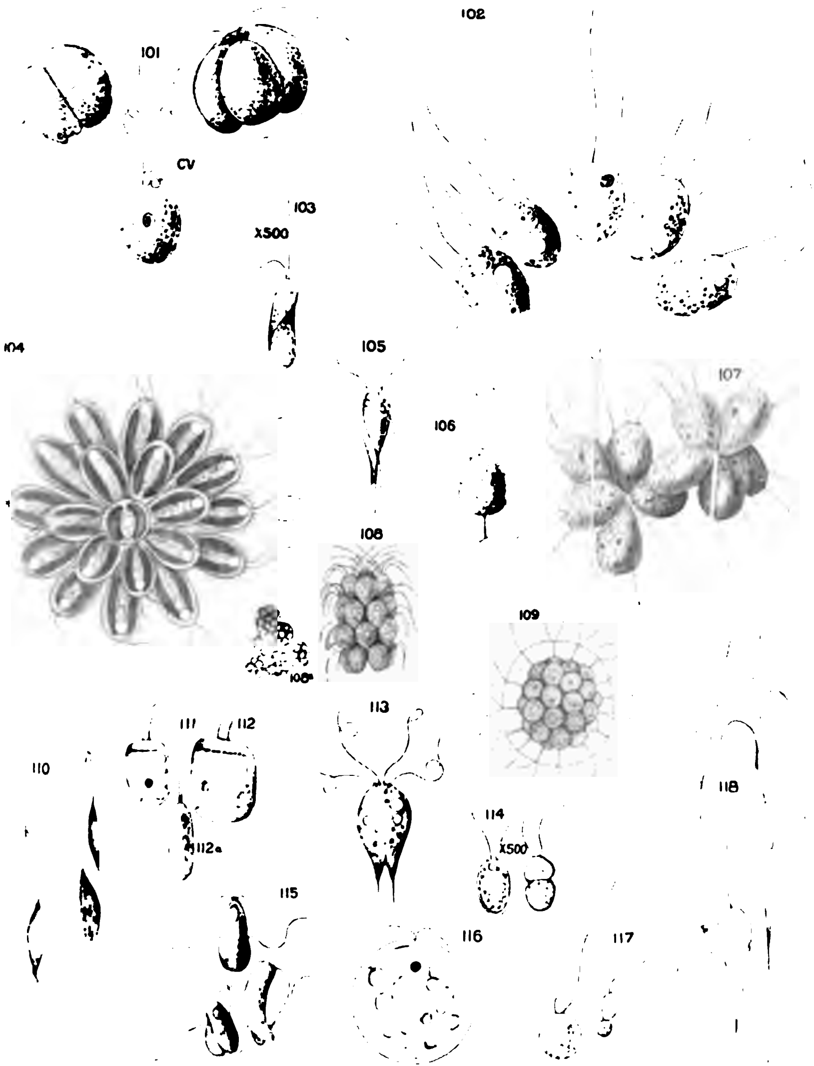

101
CV
102
103
X500
104
105
106
107
108
108a
109
110
111
112
112a
113
114
X500
115
116
117
118

PLATE X; FIGS. 119 TO 135; MAGNIFIED 500 DIAMETERS.

Figs. 119 to 123 are varieties of the genus *Holophrya* for which no specific determinations have been made.......................p. 43
Figs. 124 to 126 are provisionally placed in the genus *Enchelys*......................p. 44
Fig. 127. *Ulotricha farcta* C. & L..............p. 43
Fig. 128. *Enchelys pupa* (?) Ehr...............p. 44
Fig. 129. *Spathidium* sp. (?)....................p. 44
Fig. 130. *Balantozoon agile* Stokes..............p. 43
Fig. 131. *Spathidium spathula* Duj.............p. 44
Fig. 132. *Holophrya* (?).........................p. 43
Fig. 133. *Lionotus* sp. (?)......................p. 51
Fig. 134. *Enchelys* sp. (?).....................p. 44
Fig. 135. *Mesodinium* sp. (?)..................p. 51

PLATE X.

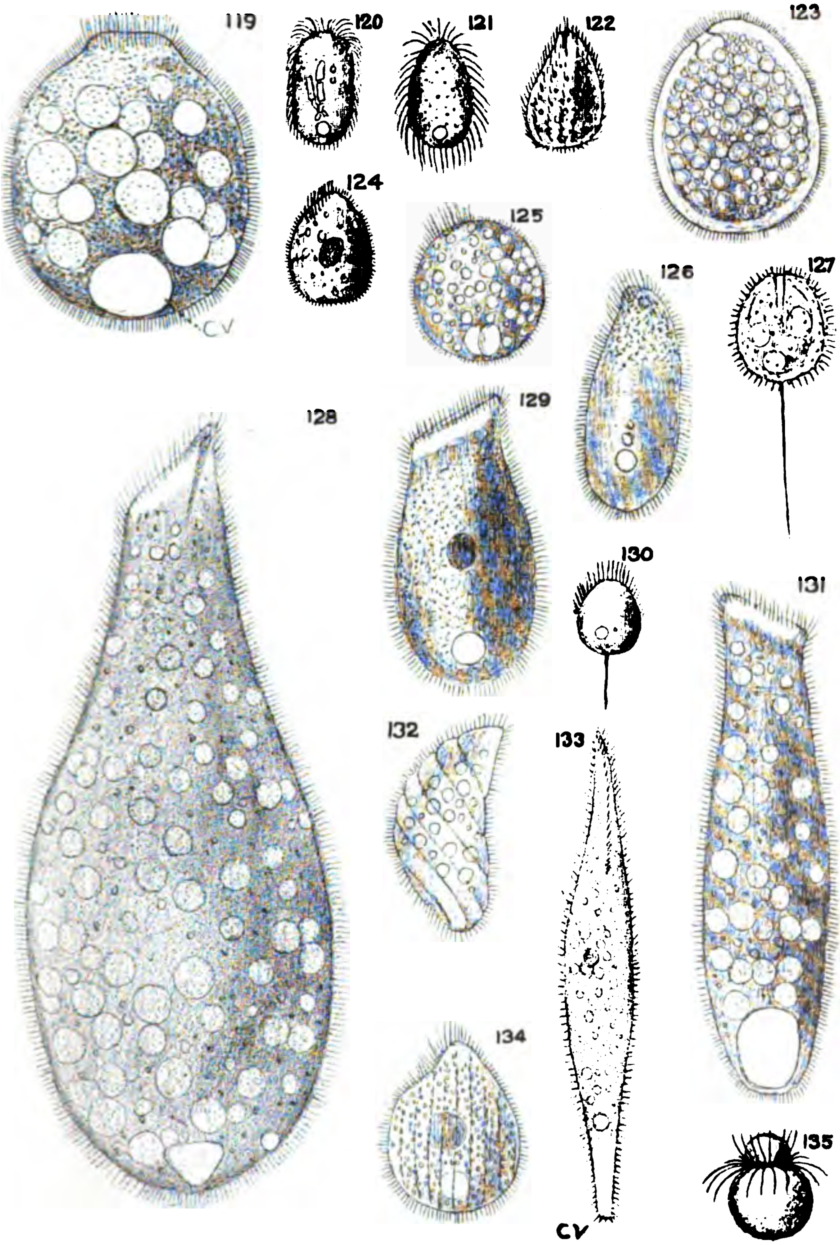

119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
CV
CV

PLATE XI; FIGS. 136 TO 148; MAGNIFIED 500 DIAMETERS.

PLATE XI.

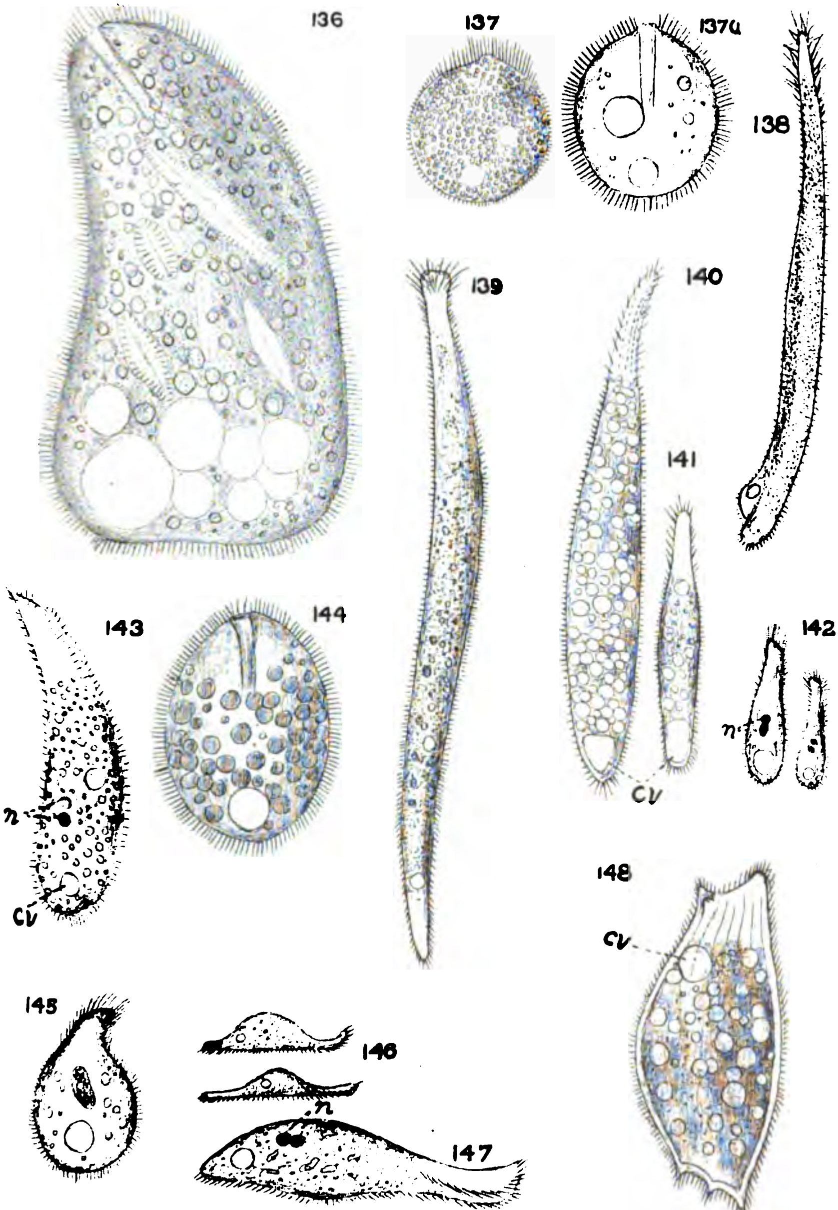
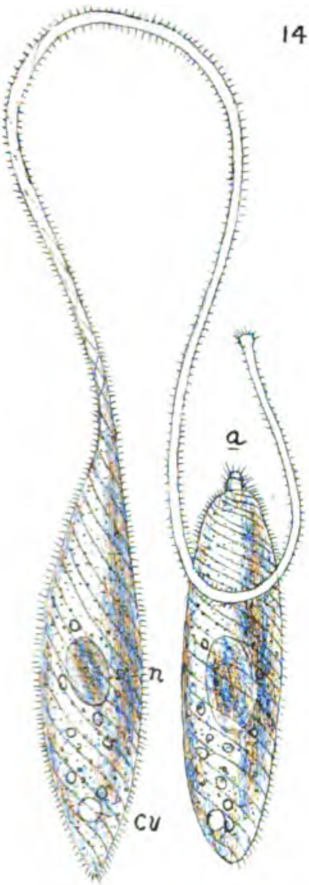

136
137
137a
138
139
140
141
142
n
143
n
cv
144
cv
148
cv
145
146
n
147

PLATE XII; FIGS. 149 TO 155; MAGNIFIED 500 DIAMETERS.

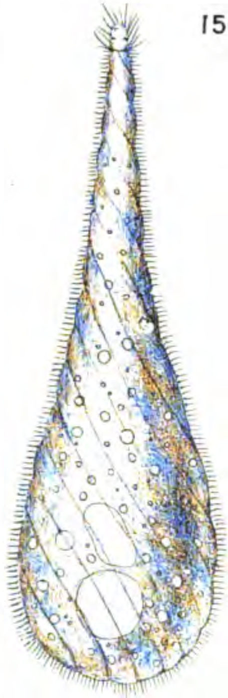
Fig. 149. *Lacrymaria olor* O. F. Müll. Fig. 149*a* is the same animal contracted........p. 45
Fig. 150. *Lacrymaria* sp. (?)....................p. 45
Fig. 151. *Amphileptus* sp. (?)..................p. 46
Fig. 152. *Lacrymaria lagenula* C. & L..........p. 45
Fig. 153. *Coleps hirtus* O. F. Müll..............p. 42
Fig. 154. *Loxodes rostrum* O. F. Müll...........p. 52
Fig. 155. *Lionotus wrzesmowsky* S. K...........p. 51

PLATE XII.

149



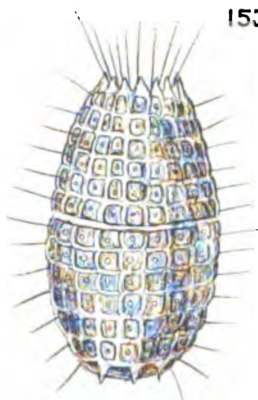
150



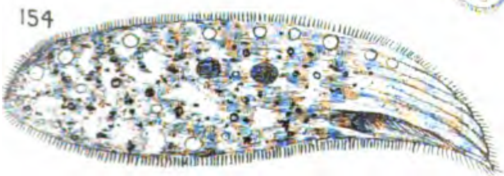
151

152

153



154



155

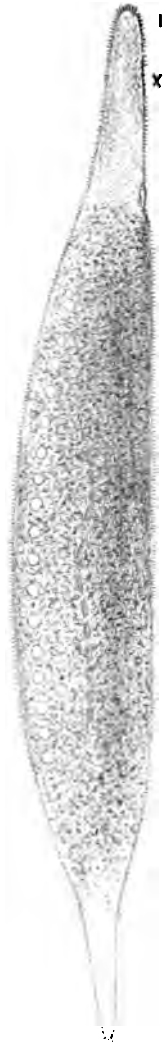
PLATE XIII; FIGS. 156 TO 160; MAGNIFIED 450 DIAMETERS.

Fig. 156. *Trachelophyllum* sp. (?)................p. 45
Fig. 157. *Dileptus monilatus* Stokes............p. 46
Fig. 158. *Dileptus gigas* (?) C. & L............p. 46
Fig. 159. *New genus*.............................p. 52
Fig. 160. *Dileptus* sp (?).......................p. 46

PLATE XIII.

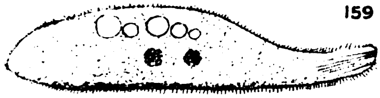
156

157



158

159



160

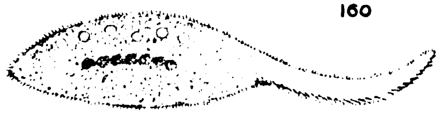


PLATE XIV; FIGS. 161 TO 173; MAGNIFIED 500 DIAMETERS.

PLATE XIV.

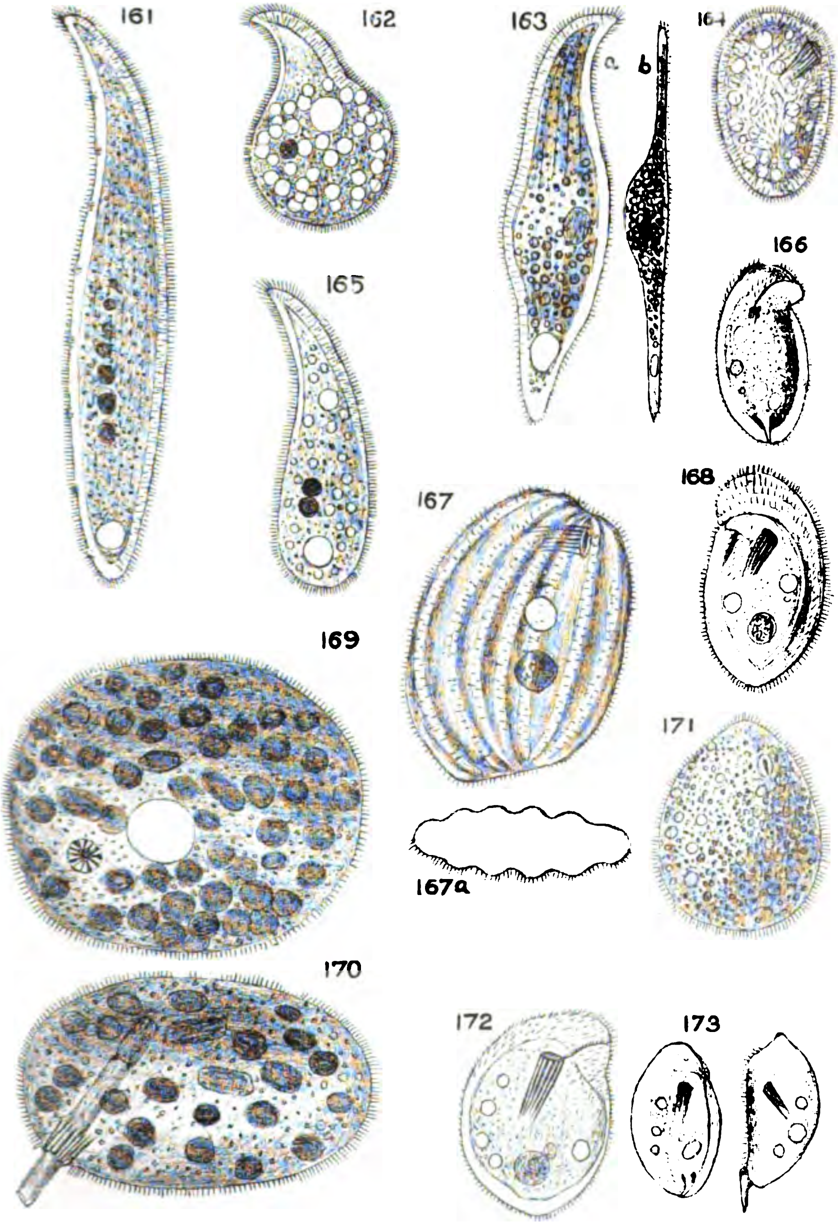


PLATE XV; FIGS. 174 TO 184; MAGNIFIED 500 DIAMETERS.

Fig. 174. *Chilodon cucullus* Müll................p. 52
Fig. 175. *Dallasia frontinia* Stokes.............p. 49
Fig. 176. *Colpidium striatum* Stokes............p. 49
Fig. 177. *Colpidium* sp. (?)....................p. 49
Fig. 178. *Colpidium* sp. (?)....................p. 49
Fig. 179. *Colpidium* sp. (?)....................p. 49
Fig. 180. *Chilodon vorax* Stokes...............p. 52
Fig. 181. *Uronema marina* Duj.................p. 49
Fig. 182. *Glaucoma scintillans* Ehr.............p. 49
Fig. 183. *Colpidium* sp. (?)....................p. 49
Fig. 184. *New genus* (?). Upper figure as seen from the end, lower figure from the side ....p. 53

PLATE XV.

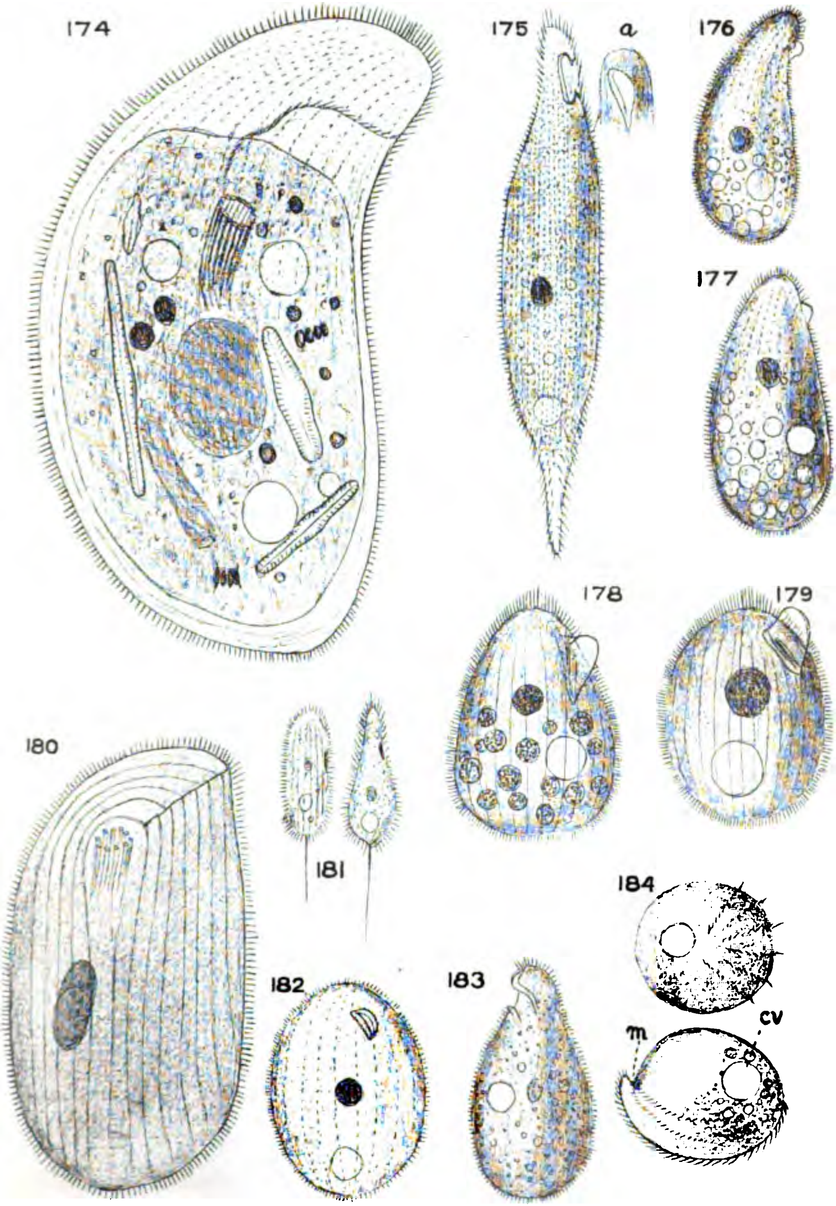


PLATE XVI; FIG. 185; MAGNIFIED 400 DIAMETERS.

Fig. 185. *Frontonia* sp. (?) ....p. 47

PLATE XVI.

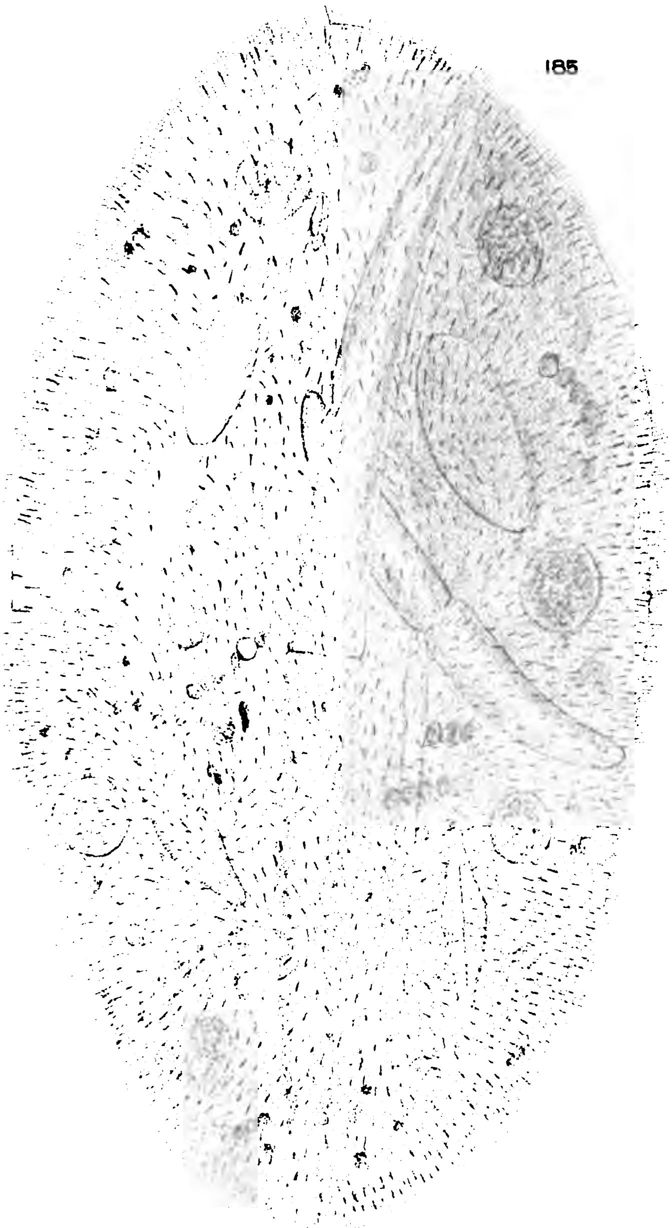
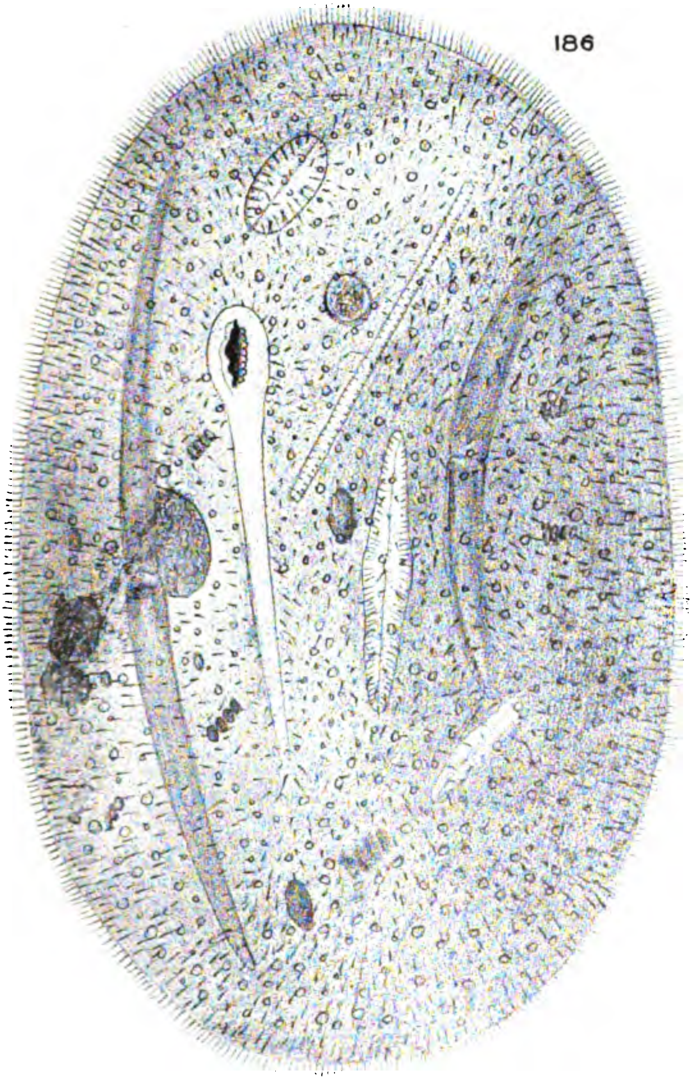


PLATE XVII; FIGS. 186 TO 193; MAGNIFIED 500 DIAMETERS

PLATE XVII.

186

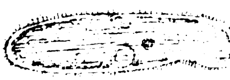


187

188

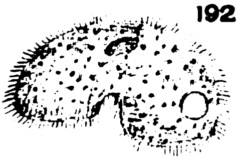
189

191



190

192



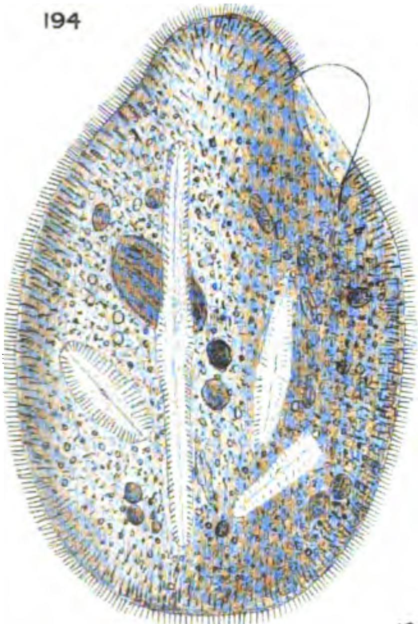
193

Plate XVIII; Figs. 194 to 200; Magnified 500 Diameters.

Fig. 194. *Colpidium* sp. (?) .... p. 49
Fig. 195. *Colpoda* sp. (?) .... p. 48
Fig. 196. *Colpoda cucullulus* Ehr. .... p. 48
Fig. 197. *Dexiotricha plagia* Stokes .... p. 50
Fig. 198. *Frontonia* sp. (?) .... p. 47
Fig. 199. *Chaenochilum margaritaceum* Ehr. ...... p. 50
Fig. 200. *Microthorax sulcatus* Ehr. .... p. 50

PLATE XVIII.

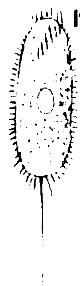
194



195

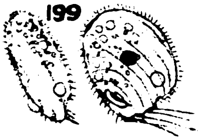
196

197



198

199



200

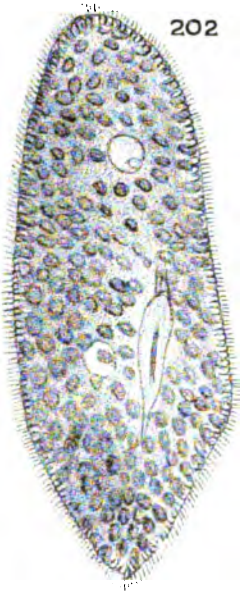
PLATE XIX; FIGS. 201 TO 207; MAGNIFIED 500 DIAMETERS.

Fig. 201. *Paramecium bursaria* Ehr............p. 48
Fig. 202. *Paramecium bursaria*..................p. 48
Fig. 203. *Paramecium caudatum* Ehr...........p. 48
Fig. 204. *Lambadion bullinum* Perty............p. 50
Fig. 205. *Colpoda* sp. (?)........................p. 48
Fig. 206. *Paramecium trichium* Stokes..........p. 48
Fig. 207. *Trichoda pura* Ehr....................p. 49

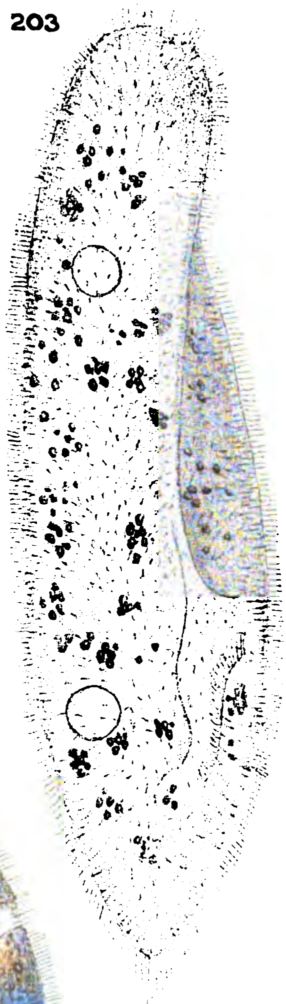
PLATE XIX.

201

202

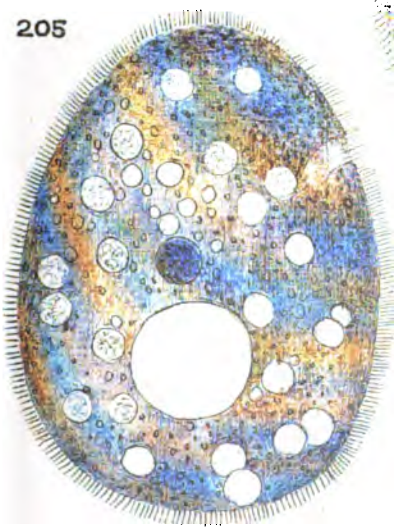


203



204

205



206

207

PLATE XX; FIGS. 208 TO 221; MAGNIFIED 500 DIAMETERS.

PLATE XX.

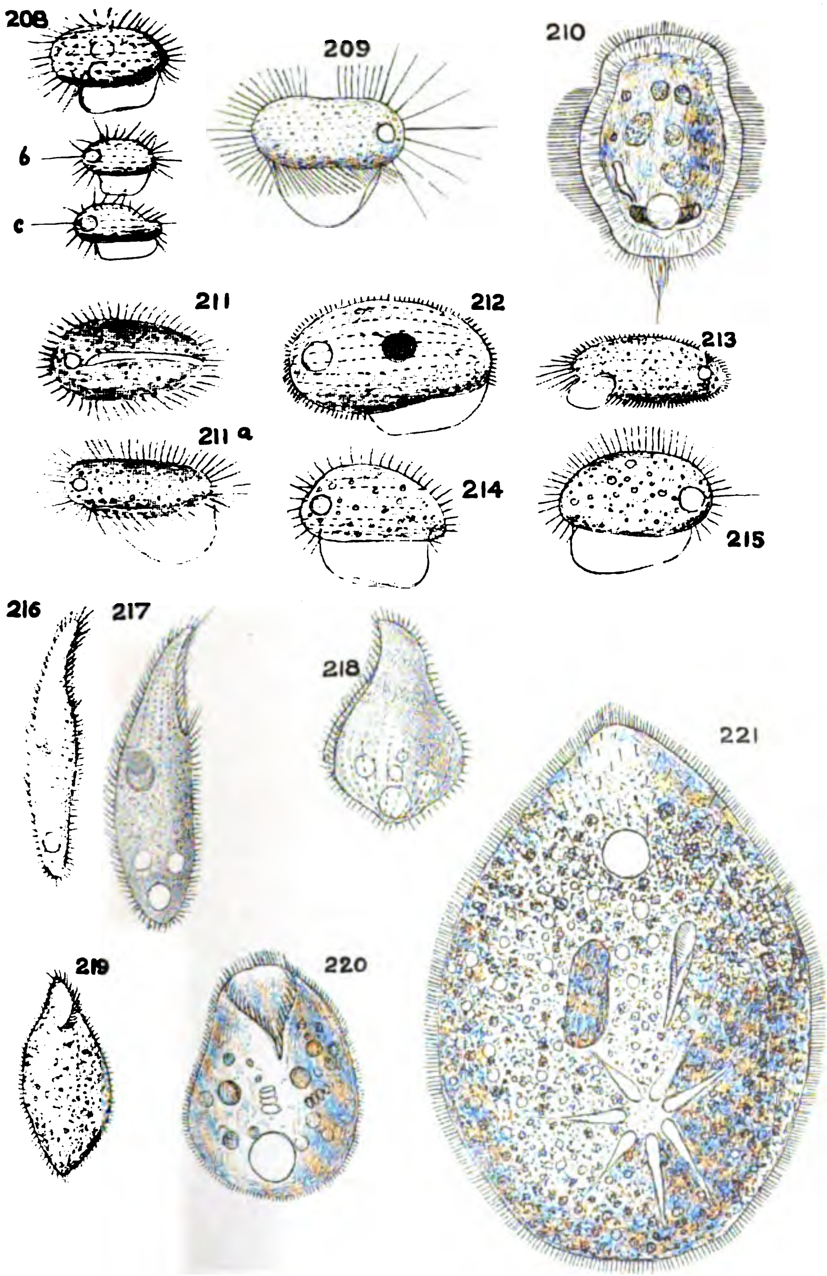


PLATE XXI; FIGS. 222 TO 230; MAGNIFIED 500 DIAMETERS.

PLATE XXI.

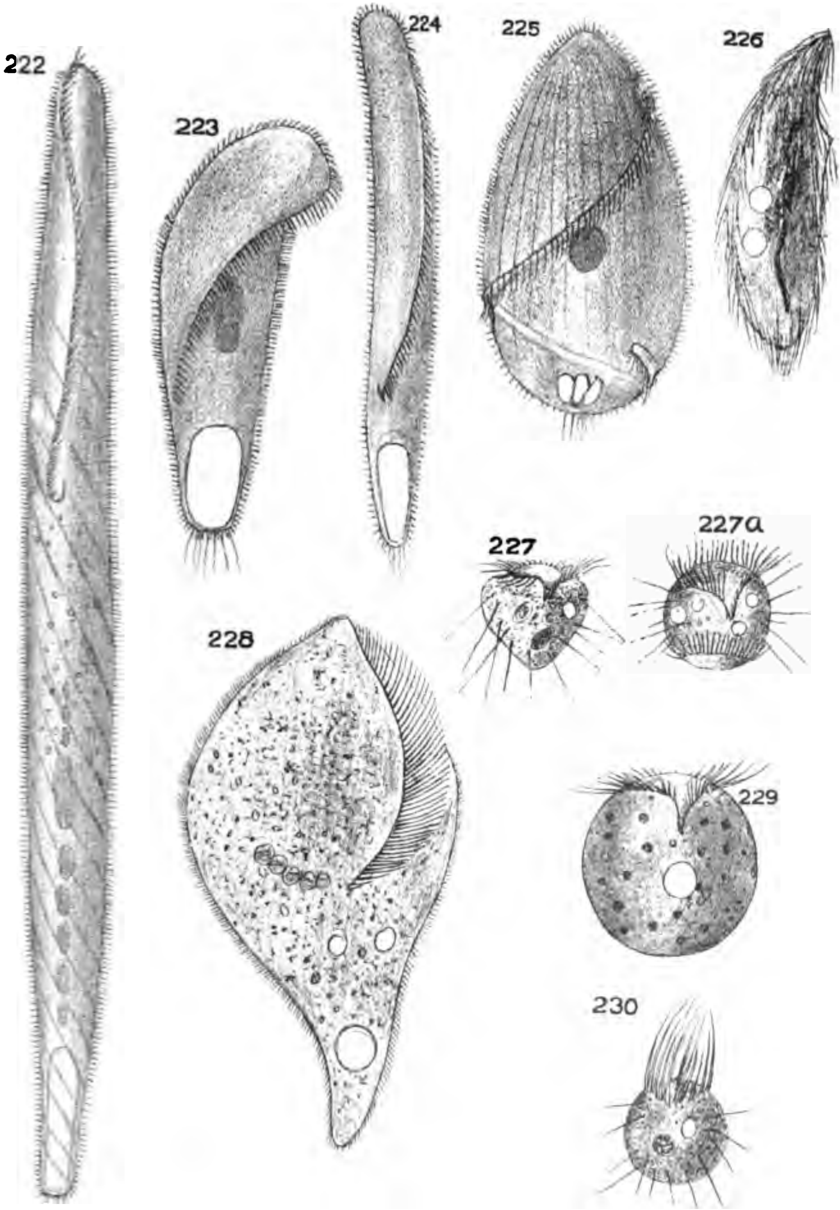
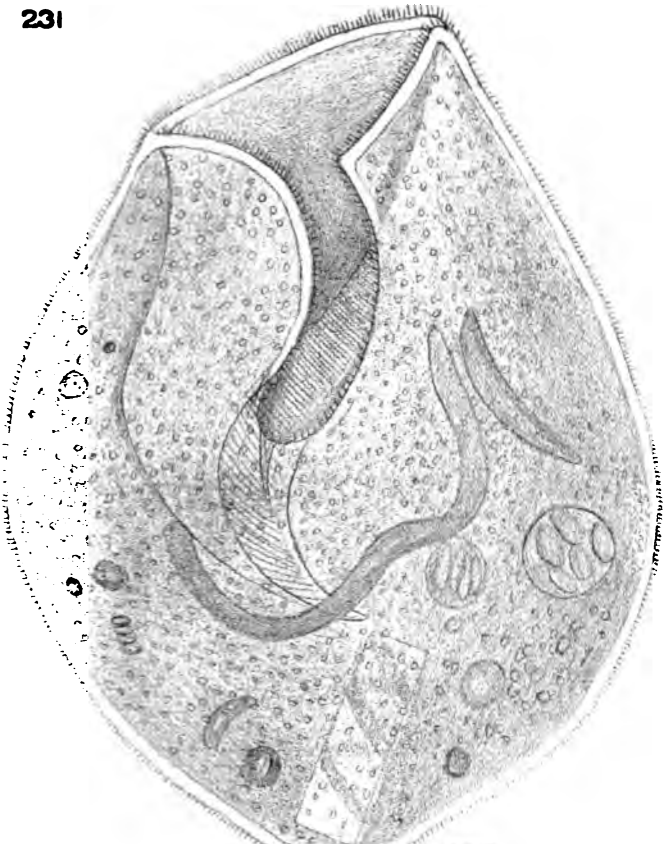
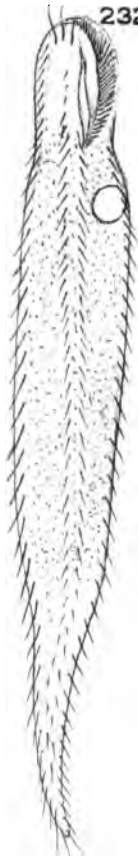


PLATE XXII; FIGS. 231 TO 236; MAGNIFIED 500 DIAMETERS.

PLATE XXII.


231

X200


232


233

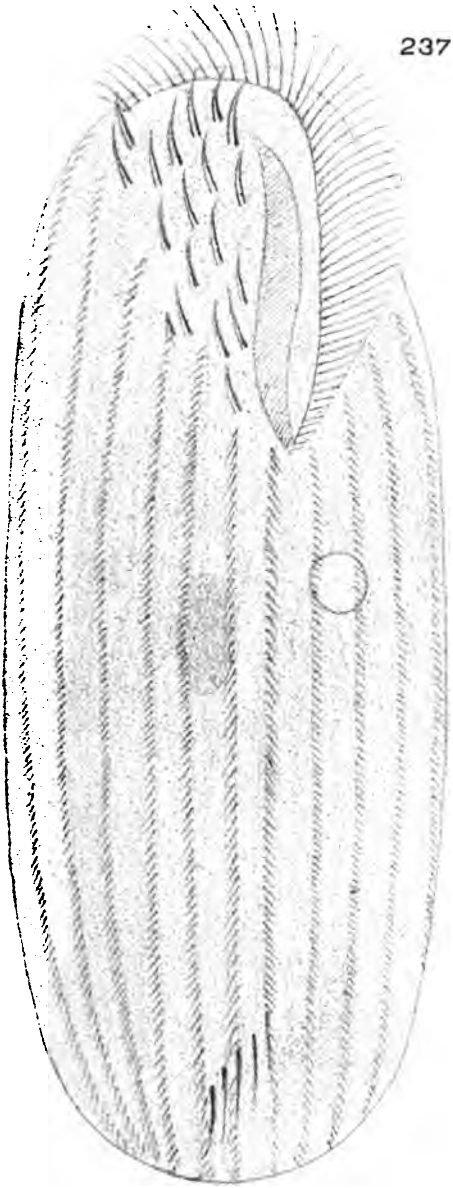

234

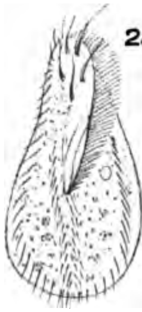

235


236

PLATE XXIII: FIGS. 237 TO 239; MAGNIFIED 500 DIAMETERS.

PLATE XXIII.


237


238

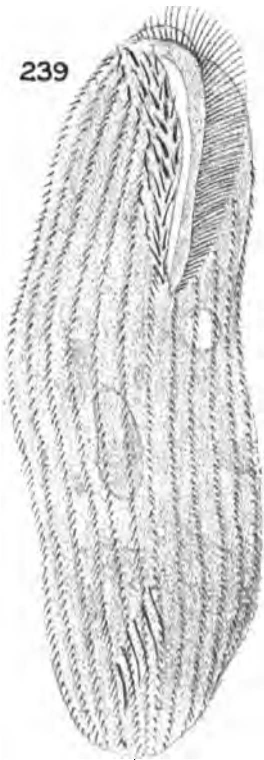

239

Plate XXIV; Figs. 240 to 244; Magnified 500 Diameters.

Fig. 240. *Stentor cœruleus* Ehr................p. 55
Fig. 241. *Urostyla trichogaster* Stokes..........p. 58
Fig. 242. *Holosticha* sp. (?)....................p. 60
Fig. 243. *Uroleptus dispar* Stokes..............p. 58
Fig. 244. *Holosticha vernalis* Stokes............p. 60

PLATE XXIV.

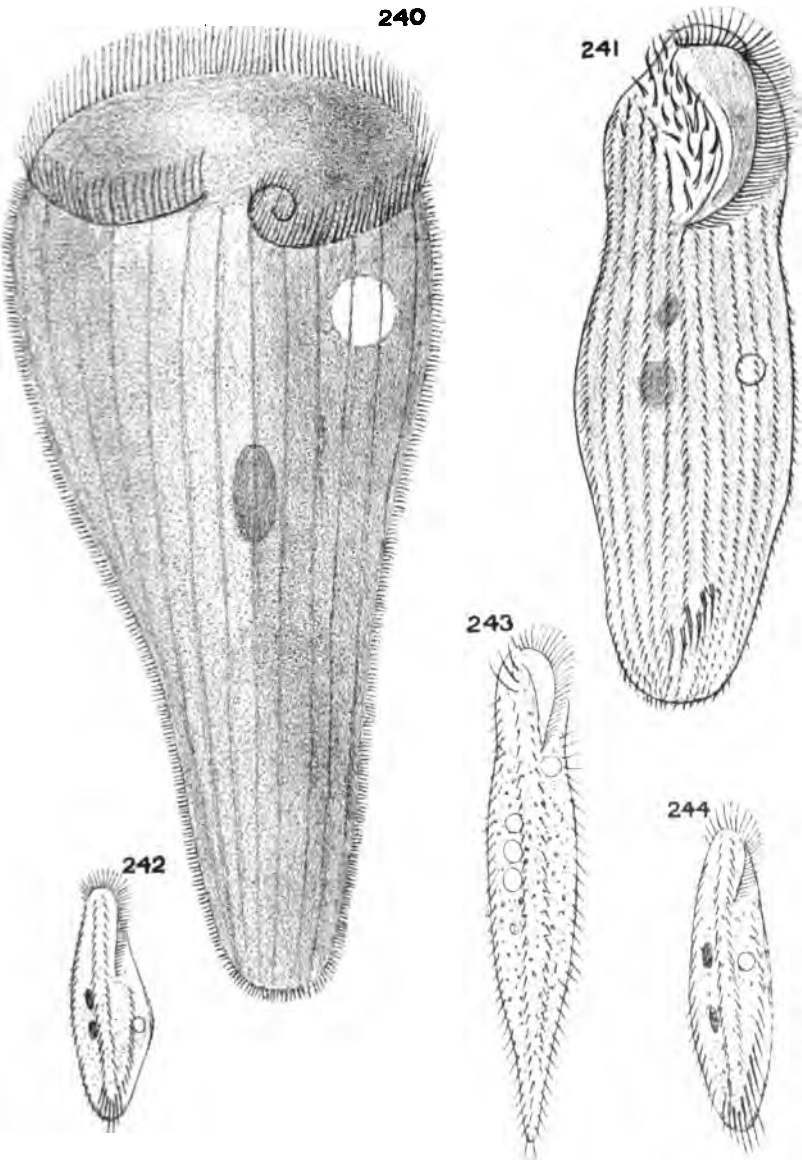
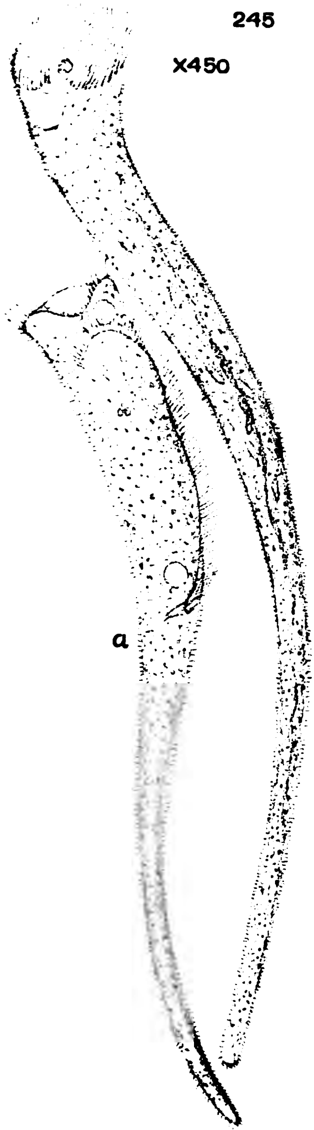


PLATE XXV; FIGS. 245 TO 246; MAGNIFIED 450 DIAMETERS.

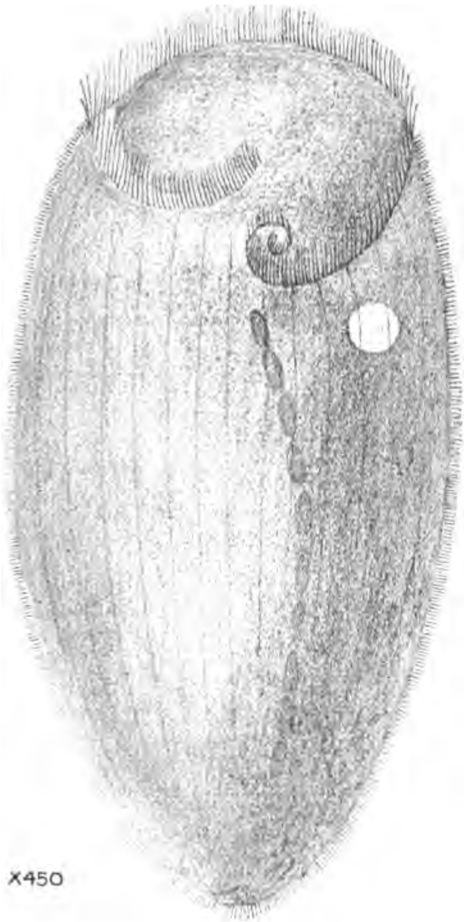
PLATE XXV.

245



X450

246

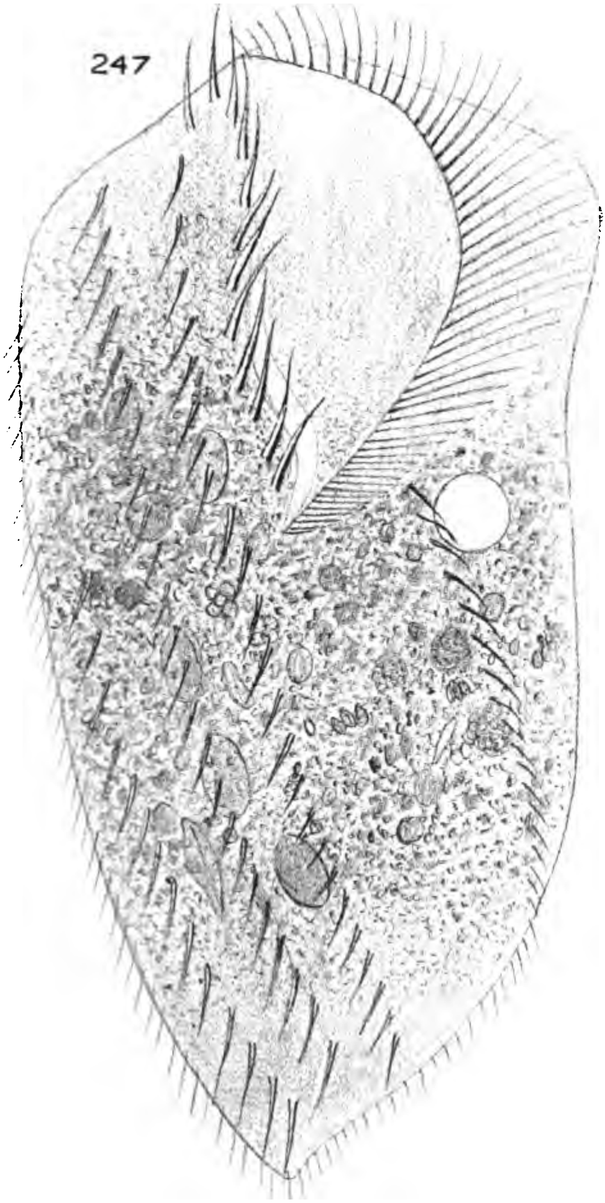


X450

PLATE XXVI; FIGS. 247 TO 249; MAGNIFIED 500 DIAMETERS.

PLATE XXVI.

247



248

249

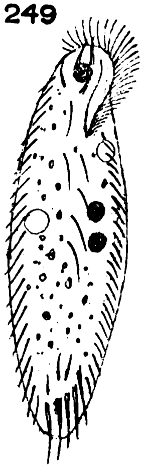
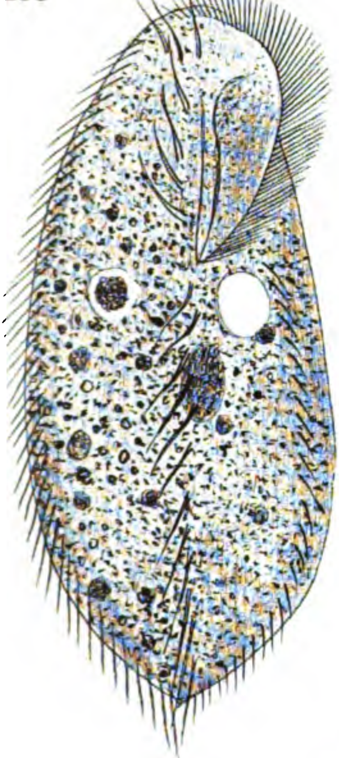


PLATE XXVII; FIGS. 250 TO 257; MAGNIFIED 500 DIAMETERS.

PLATE XXVII.

250



251

252

253

254

256

257

255

PLATE XXVIII; FIGS. 258 TO 262; MAGNIFIED 500 DIAMETERS.

PLATE XXVIII.

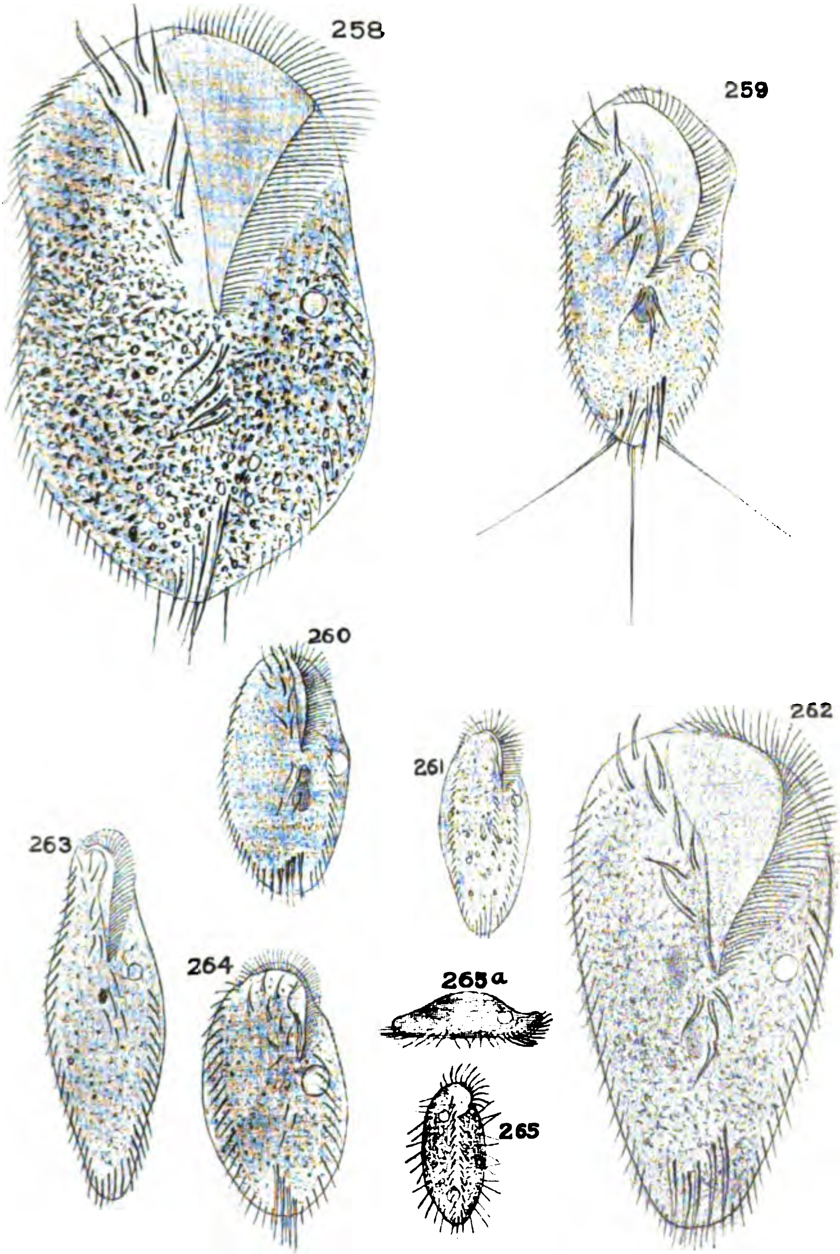
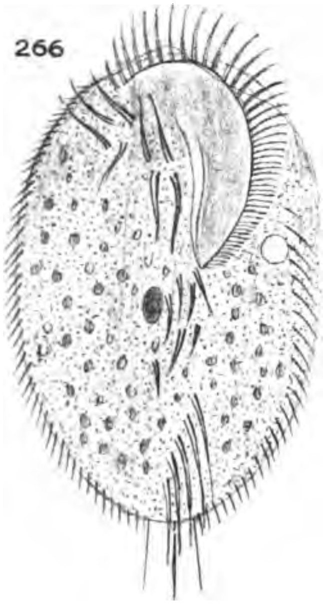


PLATE XXIX; FIGS. 266 TO 272; MAGNIFIED 500 DIAMETERS.

Fig. 266. *Stylonychia pustulata* Ehr............p. 60
Fig. 267. *Stylonychia* sp. (?)....................p. 60
Fig. 268. *Euplotes* sp. (?).......................p. 61
Fig. 269. *Stylonychia putrina* Stokes...........p. 60
Fig. 270. *Euplotes carinata* Stokes.............p. 61
Fig. 271. *Euplotes plumipes* Stokes.............p. 61
Fig. 272. *Euplotes charon* Ehr.................p. 61

PLATE XXIX.

266

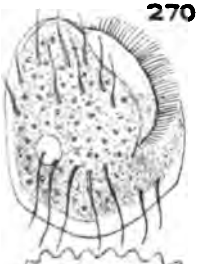


267

268

269

270



270a

271

272

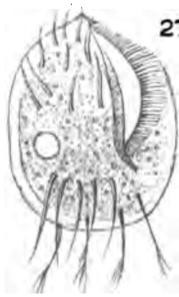


PLATE XXX; FIGS. 273 TO 279; MAGNIFIED 500 DIAMETERS.

Fig. 273. *Stylonychia mytilis* Müll. . . . . .p. 60
Figs. 274 to 277 are different forms of *Vorticella*. . . .p. 63
Fig. 278. *Rhabdostyla brevipes* (?) C. & L. . . . . .p. 64
Fig. 279. *New genus*. . . . . .p. 58
Fig. 280. *Aspidisca* sp. (?). . . . . .p. 61
Fig. 281. *Aspidisca costata* Duj. . . . . .p. 61

PLATE XXX.

273

274

275

276

277

278

279

280

281

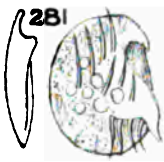
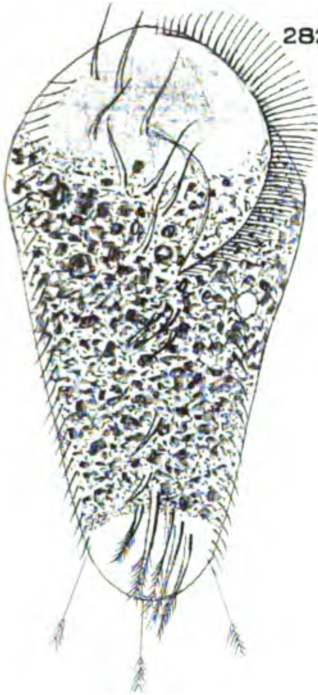


PLATE XXXI; FIGS. 282 TO 286; MAGNIFIED 500 DIAMETERS.

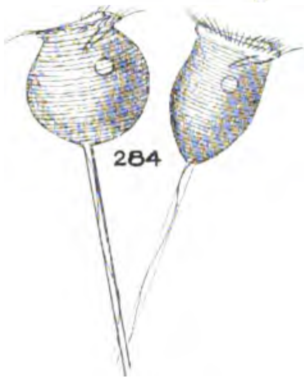
PLATE XXXI.

282



283

284



285

286

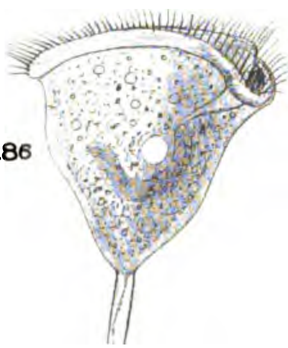
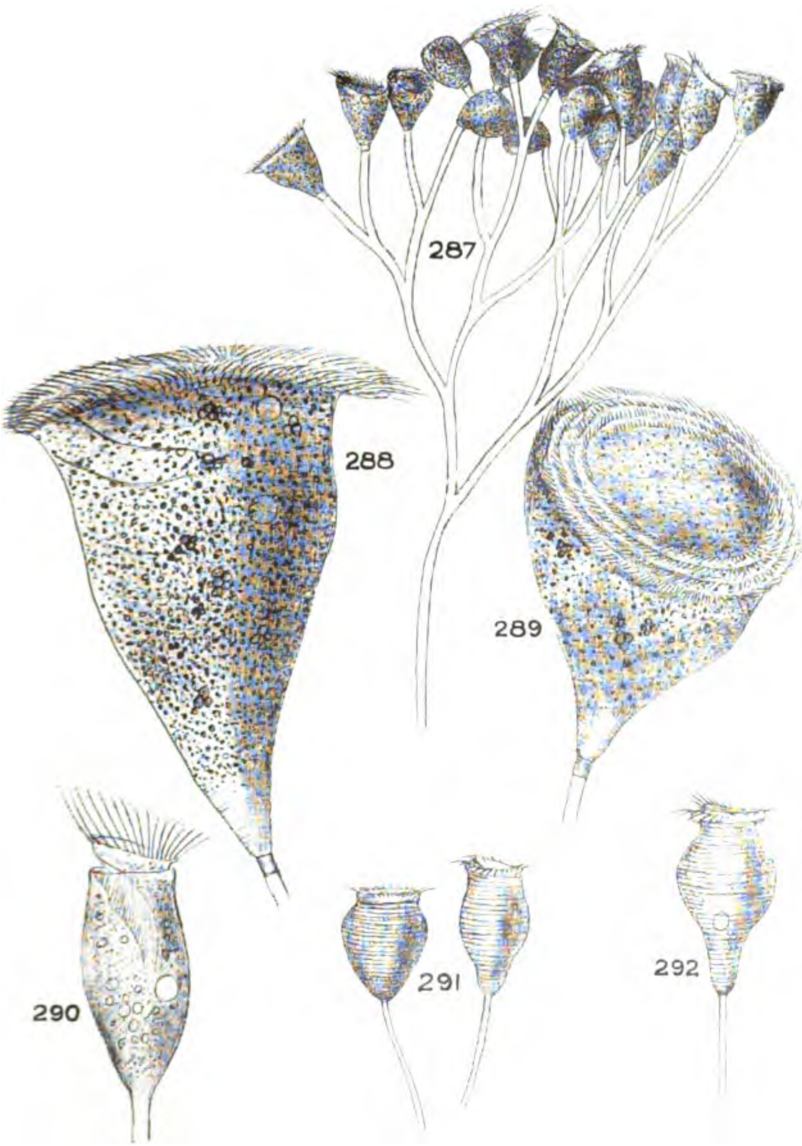


PLATE XXXII; FIGS. 287 TO 292; MAGNIFIED 500 DIAMETERS.*

* Except Fig. 287.

PLATE XXXII.



287

288

289

290

291

292

PLATE XXXIII FIGS. 293 TO 298; MAGNIFIED 500 DIAMETERS.

Figs. 293 and 294 are forms of *Vorticella*..........p. 63

Fig. 295. *Rhabdostyla brevipes* (?) C. & L. This is certainly a different species from Fig. 278..........................p. 64

Fig. 296. *Vorticella* ....p. 63

Fig. 297. *Opercularia* sp. (?) *a* is a single individual, and *b* is the form assumed when contracted ....p. 65

Fig. 298. *Vorticella* ....p. 63

PLATE XXXIII.

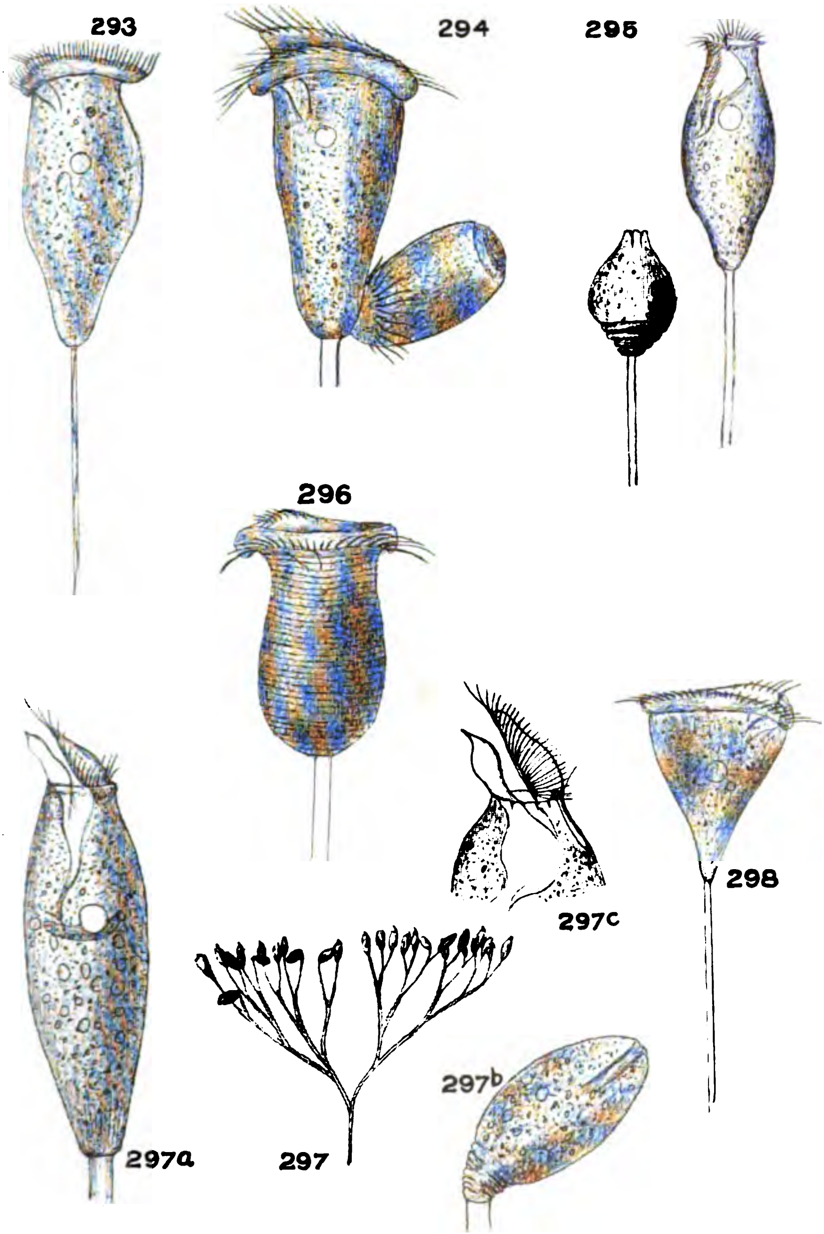


PLATE XXXIV; FIGS. 298 TO 303; MAGNIFIED 500 DIAMETERS.*

Fig. 299. *Carchesium polypinum* Linn. *a* is an expanded colony. *b* is a piece of a single branch magnified so as to show the ending of the individual muscles at the base of each stalk. *c* represents two individuals magnified 500 diameters...p. 64

Fig. 300. *Podophrya* sp. (?) Showing terminal cilia ....p. 66

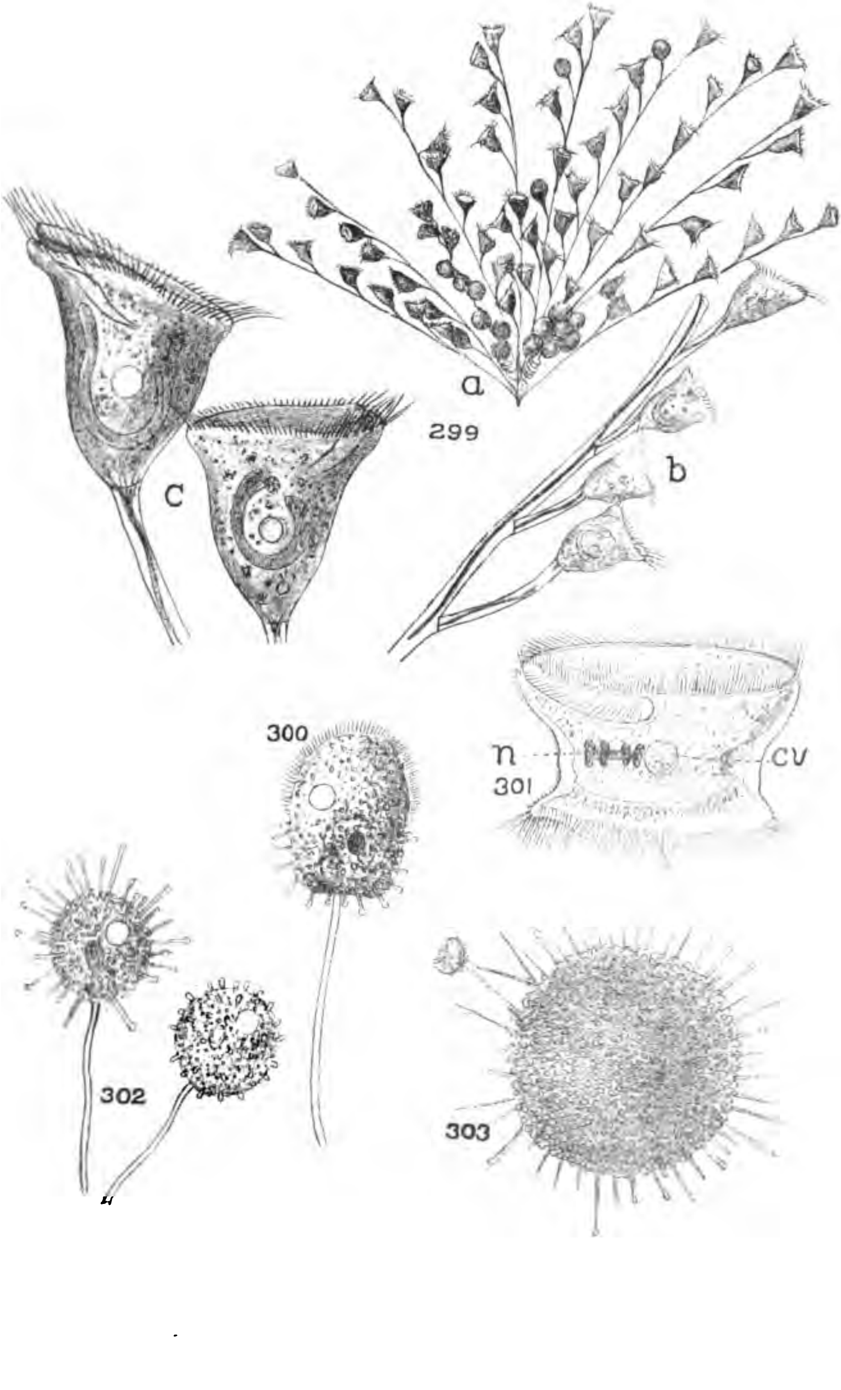
Fig. 301. *Trichodina pediculus* Ehr.............p. 63

Fig. 302. *Podophrya* sp. (?)....................p. 66

Fig. 303. *Sphærophrya* sp. (?)..................p. 65

* Except Fig. 299 *a* and *b*.

PLATE XXXIV.



State of Connecticut

State Geological and Natural History Survey

BULLETIN No. 3

A PRELIMINARY REPORT
ON THE
HYMENIALES OF CONNECTICUT

By

EDWARD ALBERT WHITE, B.S.

Professor of Botany, Forestry, and Landscape Architecture, Connecticut Agricultural College

State of Connecticut

PUBLIC DOCUMENT No. 47

State Geological and Natural History Survey

COMMISSIONERS

HENRY ROBERTS, Governor of Connecticut *(Chairman)*
ARTHUR TWINING HADLEY, President of Yale University
BRADFORD PAUL RAYMOND, President of Wesleyan University
FLAVEL SWEETEN LUTHER, President of Trinity College *(Secretary)*
RUFUS WHITTAKER STIMSON, President of Connecticut Agricultural College

SUPERINTENDENT

WILLIAM NORTH RICE

BULLETIN No. 3

HARTFORD PRESS
The Case, Lockwood & Brainard Company
1905

A Preliminary Report

on the

Hymeniales of Connecticut

By

EDWARD ALBERT WHITE, B.S.
Professor of Botany, Forestry, and Landscape Architecture, Connecticut
Agricultural College

HARTFORD PRESS
The Case, Lockwood & Brainard Company
1905

Preface.

For several years, work along the line of investigations in fleshy and woody fungi has been carried on in many states, but little has ever been reported on Connecticut species. The establishment of the State Geological and Natural History Survey has made possible the contributing of some knowledge regarding fleshy and woody fungi of this state, and for this purpose the following preliminary report on the Hymeniales of Connecticut has been prepared.

The aim in the preparation of this report has not been to prepare original keys, monographs of different groups, or technical descriptions of species; the time since the organization of the Survey has been too short for such original work; but the aim has been to compile as far as possible a complete and accurate list of native species, together with notes regarding the characteristics of the genera. To make the report more comprehensible, technical terms have been avoided when it has been possible to do so without detriment to accuracy of description.

The collecting this year has been done largely in the vicinity of Mansfield, representing the northeastern section of the state, from which section two hundred and seventy-five species, included in fifty-five genera, are reported. Four hundred and twenty-five numbers were collected.

The writer fortunately has had access to several excellent collections previously made in various sections of the state, making possible a much more complete list of native species.

These collections are Mr. C. C. Hanmer's of East Hartford, representing the species found in central Connecticut; that of Dr. L. M. Underwood, Professor of Botany, Columbia University, New York City, whose collection made in Goshen represents the western Connecticut species; and that of Dr. G. P. Clinton, Botanist of the Connecticut Experiment Station at New Haven, representing the species of southwestern Connecticut.

From Mr. Hanmer's collection have been listed one hun-

dred and eighty species, included in fifty genera; from Dr. Underwood's, eighty species, in twenty-seven genera; and from Dr. Clinton's, thirty-four species, in twenty-two genera. The species found in the different sections of the state are the same in many cases, as is shown in the list appended. The total number of different species listed is three hundred and seventy-five, included in sixty-five different genera.

The mushrooms collected under the writer's supervision have been carefully dried, pressed, and preserved, forming the basis of a state herbarium of fleshy and woody fungi. The number of each specimen in this herbarium is inserted with the species reported, and thus the plant may be easily referred to. A card catalogue accompanies this herbarium.

The specimens in the other collections mentioned are also carefully and systematically preserved and are accessible: Mr. Hanmer's private collection at East Hartford, Dr. Underwood's in the cryptogamic herbarium of Columbia University, and Dr. Clinton's in the herbarium of the Connecticut Experiment Station.

Saccardo's "Sylloge Fungorum" has been adopted as a basis for nomenclature.

Every effort has been made to have correctly named all specimens collected, and men who have had long experience in determining species have very willingly aided in the work. Nearly all specimens have been submitted for accuracy of determination to Professor G. F. Atkinson of the Department of Botany, Cornell University, and to Dr. C. H. Peck, the New York State Botanist. Mr. C. H. Kauffman of the University of Michigan has very kindly identified many specimens of Cortinarius. Mr. I. W. Patterson, a student at the Connecticut Agricultural College, has assisted greatly in collecting, drying, pressing, and classifying specimens. The services of all of these gentlemen are greatly appreciated. We are indebted to the libraries of the Massachusetts Agricultural College and of the Connecticut Experiment Station for the loan of scientific literature.

The writer wishes especially to express his appreciation of the assistance of Dr. Charles Thom, Mycologist for the United States Department of Agriculture in dairy investigations at

the Storrs Experiment Station. Dr. Thom has aided much in the determination of species and in manuscript reading. Mr. C. C. Hanmer of East Hartford has also shown a deep interest in the work, and has heartily coöperated in every way possible.

The writer spent several weeks in the laboratories of Professors Atkinson, Peck, and Underwood, studying their type specimens and consulting the excellent American and foreign literature in their libraries.

The photographs for illustration were taken by the writer from specimens collected in Mansfield during the past summer, with the exception of Plates III and VI, which were loaned by the Connecticut Experiment Station, and Plates V, VII, XII, XXIV, XXV, and XXVI, loaned by Professor G. F. Atkinson, and for these additions the writer feels deeply grateful. The keys which are used have been largely compiled and revised to suit Connecticut genera.

As it has not been possible to prepare original monographs of any of the genera, this report is to be regarded as preliminary to further investigations. It would be highly desirable, in the event of the State Geological and Natural History Survey being continued for a number of years, if each year additions were made to the list already published, and some group or groups monographed. Reports of this nature would rapidly increase the literature of the Connecticut species of fleshy and woody fungi.

Contents.

HYMENIALES (*Hymenomycetineae*).

HYMENIUM OR MEMBRANE FUNGI.

The Hymeniales are members of a large class of Fungi whose reproductive bodies, or spores, arise from cells of definite shape, known as *basidia*. Because of these basidial cells these fungi are classed as BASIDIOMYCETES. These basidia are microscopic, and are usually more or less club-shaped, with lateral branches, known as *sterigmata,* extending from the larger end. Within the basidia two nuclei unite, and, upon subsequent division, each portion of the divided nucleus passes through the sterigmata into a developing basidiospore.

In Hymeniales, the *sterigmata* are usually four in number on each basidium, but in some species there may be two, six, or eight, each bearing at the tip the reproductive body or *spore.* These spores, upon germination, reproduce the particular species of fungi upon which they were borne.

In the higher orders of Basidiomycetes, as in Hymeniales, these basidia are borne upon a more or less conspicuous fruiting-body, or sporophore, which constitutes the visible portion of what is commonly spoken of as the mushroom, or fleshy fungus. The older writers did not include in Basidiomycetes the lower orders, such as Ustilaginales and Uredinales, because of the absence of the complex fruit-body, but careful research by later scientists has proved the development of the spore from the union of the nuclei of the basidia; this fact has seemed to some writers to justify their classification as lower forms of Basidiomycetes.

Because of the varying methods of nuclear fusion in the basidial cells, their subsequent division and subdivision, and the further development of the sporophore, or fruit-body, this class is sometimes divided into four sub-classes: HEMIBASIDIOMYCETES, ÆCIDIOMYCETES, PROTOBASIDIOMYCETES, and EUBASIDIOMYCETES. In Hemibasidiomycetes are included such plants as the wheat and corn smuts, and in Æcidiomycetes the various rusts affecting agricultural crops. The Pro-

tobasidiomycetes and Eubasidiomycetes are considered the true Basidiomycetes; the first sub-class including Auriculariales (Auriculariineæ) and Tremellales (Tremellineæ); the second sub-class including Dacryomycetales (Dacryomycetineæ), Exobasidiales (Exobasidiineæ), and Hymeniales (Hymenomycetineæ). The Auriculariales include plants of a gelatinous or cartilaginous consistency, and are more or less ear-shaped; the Tremellales are jelly-like when moist, becoming hard, tough, and horny when dry. The first order of Eubasidiomycetes includes such plants as Guepinia; the second order includes azalea apples and other plants which are parasitic in the tissues of living plants, often deforming them; the third order, Hymeniales, constitutes the subject of this report.

The following key to the families of Hymeniales is adopted, with a few changes in the phraseology and in the system of notation, from Engler and Prantl's "Die Natürlichen Pflanzenfamilien."

Plants mold-like, or spider-web-like, consisting of interwoven hyphæ; basidia clustered... HYPOCHNACEÆ

Plants of firmly interwoven hyphæ; fruiting-surface consisting of basidia arranged in a palisade-like manner 1

1. Fruiting-surface smooth, only slightly roughened or wrinkled in some places..................... 2

Fruiting-surface uneven, with prominent elevations in the form of warts, spines, folds, tubes, etc..... 3

2. Fruit-body mostly of membranaceous, leathery, or woody consistency, funnel-form, capitate or branched ......................THELEPHORACEÆ

Plants mostly fleshy, rarely of a cartilaginous or leathery consistency, upright, club-shaped, capitate or branched ....CLAVARIACEÆ

3. Fruiting-surface with warts, interrupted folds, spines, or crested warts or plates.........HYDNACEÆ

Fruiting-surface of other shapes................. 4

4. Fruiting-surface with regular tubes, or with folds or more or less leaf-like plates, which partly or completely unite by running together irregularly in a honey-combed manner, or are united into labyrinthiform passages ....POLYPORACEÆ

Fruiting-surface of prominent folds (gills), or with evident leaf-like expansions or plates, which are free or regularly forked, or are united by running together irregularly only at the base or point of attachment to the pileus.................. AGARICACEÆ

AGARICACEÆ Fries. GILL-BEARING FUNGI.

This family contains by far the largest number of species of mushrooms. They are distinguished by a more or less flattened *pileus,* or *cap,* which may become convex, bell-shaped, or funnel-shaped; the *stem,* or *stipe,* is generally attached to the center, or nearly so, of the under side of the pileus; or the point of attachment may be at one side, when the pileus becomes shelving; the stem may be absent and the pileus attached directly to the mycelium (sessile).

The spore-bearing surface is usually on the under side of the pileus, and consists of radiating gills, prominent folds, or veins. Microscopical examination shows these fruiting-surfaces to be covered with peculiar reproductive cells, or basidia. From each of these basidia, one-celled spores, usually four in number, are produced.

CHARACTERISTICS OF MUSHROOMS.

In order that the various parts of a mushroom may be clearly understood, the following explanation is given.

The fleshy fruit-body of the Agaricaceæ is known as the *pileus,* or cap. Microscopical examination shows it to differ considerably from the fruit-bodies of the higher plants. There is no cellular tissue, but the structure is composed of interwoven hollow tubes, technically termed *hyphæ.* These *hyphæ* serve to conduct the food substances from the basal threads, which resemble the hyphæ, to the more highly specialized reproductive cells, the basidia. These hyphal threads which run through the center of the fruit-body, stem, cap, and gills, constitute what is technically known as the *trama.* When these hyphal threads approach the outer part of the gills, certain specialized cells arise which are spoken of as the *subhymenial layer,* and from these cells the reproductive cells, or basidia, develop. The basidia, placed closely side by side, con-

stitute the *hymenium,* from which the name Hymeniales is derived.

Certain other cells are frequently found among the basidia, which resemble them closely, but lack the sterigmata and spores; these are sterile basidia, termed *paraphyses.* Still other cells are found in the species of the Agaricaceæ, which project beyond the basidia. These cells are usually large, inflated, and in some species contain coloring matter which gives the gills characteristic colorings; these are the *cystidia.* These cystidia sometimes secrete moisture, which collects in drops on their tips.

The caps of the different species have characteristics which distinguish them from each other. Frequently the thick-walled threads which constitute the outer surface of the cap are filled with coloring matter which gives to species characteristic colorings. The green and red tints of *Russula,* the violet shades in many species of *Cortinarius,* and the distinctive colors of the different species of *Amanita* are due to this fact. These thick-walled, hyphal threads are termed the *cortex,* or *cuticle.* In many species, these threads excrete viscid or slimy substances which are peculiarities of species. In many species of *Cortinarius* it is necessary to know the viscidity of the specimen before it can be placed in its proper group. In some cases the outside, cortical layer of the hyphal threads ceases to grow as the cap increases in size; consequently it becomes torn into fine hairs, fibers, or scales of various sizes. The abundant scales of *Pholiota squarrosoides* arise from this source, as do the scales and tomentum on many other species.

The gills are the folds, or plates, on the lower surface of the cap, which radiate in various ways from the stem to the margin of the cap.

For accurate determination of genera and species, the technical terms descriptive of the gills, employed by most scientific writers, must be carefully studied and understood. These terms are so frequently met with in text-books that detailed definitions are hardly necessary in this report.

Upon the character and shape of the stem depend many of the distinguishing features in the identification of species.

In the larger number of Agarics, the stem is situated in the

center of the cap, giving these species an umbrella-like shape; but in some species the stem is attached at the side of the cap, when it is said to be *eccentric*. If the stem is entirely absent, the cap is *sessile*.

In some genera, the stem is fleshy and in others it is cartilaginous. The fleshy stems are usually more or less fibrous and somewhat spongy when broken, while the cartilaginous stems snap readily when bent, resembling somewhat the breaking of a pipestem. The outer surface of the stem is often covered with hairs or scales which arise from similar causes as those on the surface of the cap. The interior of stems varies much, being often solid throughout, but frequently hollow or stuffed with pithy substances. In shape, the stems vary in the different species; often they are large and bulbous at the base as in many species of *Amanita* and *Cortinarius;* sometimes they are cylindrical throughout, and again they taper decidedly, either toward the apex or toward the base. All of these characteristics need to be carefully considered in noting the distinct features in each specimen collected, for no two specimens are alike in every respect, even of the same species.

The *veil* and the resulting *volva,* or cup, and the *annulus,* or ring, are peculiar to certain Agarics, and need to be carefully observed, for the nature and location of these parts indicate frequently the edibility or non-edibility of the species.

In the young stage, the mushrooms exist as small knobs, or "buttons," of mycelium on the substratum. At this stage, the margin of the cap lies closely against the stem, and in some genera, as *Collybia* and *Mycena,* the margins simply expand, never having been united to the stem by any special structure. In other genera, like *Agaricus* or *Amanita,* the margins of the cap are closely united to the outer layer of the stem by a more or less compact net-work of fibers, termed the *veil.* This veil remains firm for a time, but after a while the expansion of the cap causes it to rupture. After the veil is ruptured, a part persists for a time on the cap, giving it various margins, and a part remains on the stem in the form of a ring, or, as it is technically termed, the *annulus.* The remnants on the cap and stem vary as to the length of time they remain. The more delicate the veil the more quickly it disappears, and it is

seldom found on certain species at maturity. On other species, the veil is well developed and persists both on the margin of the pileus and on the stipe for a considerable length of time. In many species of *Amanita, Agaricus,* and *Lepiota,* this persistent ring remains, while in some species of *Cortinarius* the delicate membrane quickly disappears. In *Lepiota procera* the ring is quite thick and persistent and easily movable on the stem. In some species of *Amanita,* this membrane makes a delicate curtain which completely covers the hymenial layers on the gills, and which drops around the stem, when ruptured from the margin of the cap. This veil is usually spoken of as the *partial veil.*

The genus *Amanita* possesses both a veil and a volva. A layer of fungus threads completely surrounds the fruit-body in the immature mushroom, forming what is known as the *volva,* or, as it is sometimes called, the *universal veil.* As the stem lengthens and the cap expands, this universal veil ruptures in various ways according to the species. In this rupturing, a more or less well defined "cup" is left at the base of the stem, differing in various species. In some cases, the universal veil becomes torn, and persists on the cortex of the cap in differently shaped "warts" of floccose scales. In *Amanita,* for example, the remnants of the ruptured outer veil are white, floccose, rather compact scales, which may disappear entirely in the mature plant, while in *Amanita solitaria,* the scales are found to be thick and conical, but easily rubbed off, and in *Amanita cæsarea,* frequently no indications of the ruptured veil can be found on the surface of the pileus.

The vegetative portion of the mushroom is seldom seen by the casual observer. A mass of hyphal threads composing the reproductive or fruiting body is the part noticed, the vegetative portions being hidden beneath decaying leaves, or ramifying within the cell structure of the host plant.

Key for the Analysis of Connecticut Genera of Agaricaceæ.

The Agaricaceæ are subdivided into five divisions: these divisions depending upon the color of the spores when deposited upon an opaque surface. After collecting, place the mushrooms, gills down, on opaque paper for a while, and an

abundance of spores will accumulate, making possible the following divisions:

1. *White Spores.* Spores pure white, with an occasional slight tinge of yellow or pink.

2. *Ochre Spores.* Spores yellow-brown or rust color.

3. *Rosy Spores.* Spores pink or some shade of pink.

4. *Brown Spores.* Spores dark brown or purple-brown.

5. *Black Spores.* Spores black, showing no tinge of brown or purple.

*Key to the White-Spored Group.**

	Margin of the gills acute........................	1
	Margin of the gills longitudinally split or grooved..	17
1.	Mushrooms soon decaying or shrivelling..........	2
	Mushrooms leathery, woody or corky, rigid when dry	15
2.	Gills not attached to the stem; ring, volva or both present on the stem..........................	3
	Gills attached to the stem but not extending down it (adnate or adnexed)........................	4
	Gills attached to the stem and extending down it (decurrent)	10
3.	Volva and ring present..........................	*Amanita*
	Volva present; ring absent...............	*Amanitopsis*
	Volva absent; ring present..................	*Lepiota*
4.	Volva absent; ring present.................	*Armillaria*
	Volva and ring absent..........................	5
5.	Plants tough, membranaceous or leathery, drying quickly but reviving when moistened......	*Marasmius*
	Plants fleshy	6
6.	Cap and gills very crisp and brittle..............	9
	Cap and gills not crisp and brittle................	7
7.	Gills attached to the stem by a small, sudden curve (sinuate), ...	*Tricholoma*
	Gills not sinuate..............................	8
8.	Margin of cap inrolled when young...........	*Collybia*
	Margin of cap straight against the stem when young; cap slender, bell-shaped....................	*Mycena*

* Genera not reported from Connecticut are omitted from these keys.

9. Juice of plant milky..........some species of *Lactarius*
Juice of plant not milky......................*Russula*
10. Stem attached at one side of the center of the cap (eccentric), or at its margin (lateral); growing on wood ....*Pleurotus*
Stem central 11
11. Cap and gills very crisp and brittle; juice of plant milky ....some species of *Lactarius*
Cap and gills waxy............................ 12
Cap more or less firm and fleshy................. 13
12. Plants parasitic on other fungi; gills blunt......*Nyctalis*
Plants not parasitic on other fungi; margin of gills thin, but thickened at union with cap....*Hygrophorus*
13. Gills thick and fold-like, margins blunt.....*Cantharellus*
Gills thin, margins acute...................... 14
14. Fresh stems breaking with clean, sharp ends...*Omphalia*
Fresh stems breaking with fibrous, ragged ends.*Clitocybe*
15. Plants leathery in texture; gills extending down the stem (decurrent); plants reviving when moistened 16
Plants woody or corky in texture; stem absent..*Lenzites*
16. Margin of gills toothed.....................*Lentinus*
Margin of gills not toothed....................*Panus*
17. Margin of gills split into two, revolute; growing on wood.........................*Schizophyllum*
Margin of gills somewhat crisped, gills resembling folds or wrinkles..........................*Trogia*

Key to the Ochre-Spored Group.

Gills not separating easily from the cap........... 1
Gills separating easily from the cap...........*Paxillus*
1. Young plants covered by a cobwebby veil; ring fragile when present......................*Cortinarius*
Plants not covered by a cobwebby veil........... 2
2. Ring present on the stem...................*Pholiota*
Ring absent from the stem..................... 3
3. Stem attached at one side of the cap or absent.*Crepidotus*
Stem central.................................. 4
4. Gills dissolving into a mucilaginous condition at maturity; cap thin, soft and pliable...........*Bolbitius*
Gills not dissolving at maturity................. 5

5. Gills with a small, sudden curve where joined to the stem (sinuate); cap usually covered with minute scales or fibers; stem fleshy, fibrous on the outside *Inocybe*
Gills not sinuate.............................. 6
6. Stem fleshy, fibrous; cap fleshy; gills joined squarely to the stem (adnate), or running down stem (decurrent) ....*Flammula*
Stem brittle or cartilaginous..................... 7
7. Margin of cap inrolled in young plant.........*Naucoria*
Margin of cap straight against the stem in young plant ....*Galera*

Key to the Rosy-Spored Group.

Gills not attached to the stem (free).............. 1
Gills slightly attached to the stem (adnate or adnexed) 2
Gills attached and running down the stem (decurrent) 3
1. Ring absent; volva present..................*Volvaria*
Ring and volva absent.......................*Pluteus*
2. Stem brittle; gills soon separating from stem...*Leptonia*
Stem not brittle; gills with a small, sudden curve near the stem (sinuate).................*Entoloma*
3. Stem at one side of the cap, minute or absent..*Claudopus*
Stem central 4
4. Stem fibrous; margin of cap inrolled when young.. *Clitopilus*
Stem brittle; cap with a central depression.......*Eccilia*

Key to the Brown-Spored Group.

Gills attached to the stem (adnate, adnexed, or decurrent) 1
Gills not attached to the stem (free)..........*Agaricus*
1. Ring present; volva absent.................*Stropharia*
Ring and volva absent, but veil remains attached to the margin of the cap..................*Hypholoma*
Ring, volva and veil absent.................*Psilocybe*

Key to the Black-Spored Group.

Gills more or less dissolving at maturity.......*Coprinus*
Gills not dissolving at maturity.................... 1
1. Substance of fruit-body waxy.............*Gomphidius*
Substance of fruit-body fleshy and fibrous......... 2
2. Margin of cap striate; gills not variegated...*Psathyrella*
Margin of cap not striate; gills somewhat variegated 3
3. Ring present on the stem...................*Anellaria*
Ring absent, but veil often present............*Panæolus*

AMANITA. Pers.

A name given to some esculent fungi by Galen, perhaps from Mount Amanus.

The young plant in all species of *Amanita* is covered with a universal veil, as explained in the characteristics of mushrooms. As the cap expands, this veil ruptures, leaving a more or less well-defined margin on the stem, which is technically termed the volva.

The partial veil in the immature specimen extends from the stem to the margin of the pileus, enclosing the gills, and when ruptured falls around the stem in a veil-like ring. The persistency of this ring varies in the different species. The pileus is fleshy, convex, expanding with age. It separates easily from the stem, and differs from it considerably in substance. The stems are long and usually taper somewhat towards the top. The gills are not attached to the stem; spores white.

The Amanitas are nearly always found growing on the ground, usually in open woods, but are seldom found in open fields and pastures. They possess perhaps the most striking characteristics of any of the fleshy fungi, and when once learned they are seldom mistaken for other genera. The pure white form of *A. phalloides* is sure to attract the attention of even the most inexperienced collector, and its seeming purity appeals to persons seeking varieties adapted for table use. Nevertheless it contains the most violent of the poisons found in the whole group of fleshy fungi.

The colors of *Amanita* vary from pure white, through the various tints of orange, crimson, and scarlet to the dull red

and brown tints. Because of a few species which contain deadly poison, the whole group is viewed with suspicion by the amateur collector, yet many of them are listed as edible. However, it is unsafe to class any specimens of *Amanita* in the edible list, unless one is positively sure of the botanical characteristics of each individual specimen. It is better to adhere very closely to edible species which cannot be mistaken for non-edible, than to be less cautious. The amateur collector should make a careful botanical study of this group before venturing far in his search for edible fungi. The variations in each species should be carefully noted so there may be no mistaking their identity.

Frequently it is said that all poisonous forms possess a cup-like volva at the base of the stem, but this cannot be depended upon as a reliable means of identification, for often the universal veil ruptures in such a manner that few remnants are left on the stem.

In this locality the Amanitas are seldom found in any quantity before June 15th, and are very abundant from that date until the early autumn frosts. They seem especially plentiful in the chestnut sprout-lands of the state.

McIlvaine reports twenty-seven species as occurring in the United States. Eleven were collected in Tolland County during the past summer, and one in Hartford County.

Amanita bisporiger Atk. (two-spored).
Mansfield, Aug. (89).
A new species, the description of which will soon be published by Professor Atkinson.

Amanita candida Pk. (shining white).
South Windsor, *Hanmer;* Goshen, *Underwood;* Mansfield, July, Aug. (296). Edible (McI.).

Amanita cæsarea Scop. (imperial).
Mansfield, July (79). Edible qualities uncertain.

Amanita flavo-conia Atk. (*flavus,* yellow; *conus,* cone; in allusion to color and shape of cap).
Mansfield, Aug. (87).

Amanita Frostiana Pk.
Mansfield, July (183). Poisonous.

Amanita muscaria Linn. (*musca,* a fly). Fly Amanita.
Goshen, *Underwood;* Mansfield, July, Aug. (276). Poisonous. Plate I.

Amanita muscaria Linn., var. **alba** Pk. White Fly Amanita.
Mansfield, July, Aug. (92). Poisonous.

Amanita phalloides Fr. (phallus-like).
Goshen, *Underwood;* Mansfield, July, Aug. (171). Poisonous.
Variable in color from white to dark brown. Plate II.

Amanita rubescens Fr. (becoming red).
Mansfield, Aug. (83). Edible (McI.).

Amanita strobiliformis Vitt. (having shape of a pine cone).
Rockville, *Hanmer.* Edible (Pk.).

Amanita verna Fr. (vernal).
Mansfield, July (166). Poisonous.
Resembles white form of *A. phalloides* closely, but differs in the manner of rupturing the universal veil, at base of stem.

Amanita velatipes Atk. (*velatus,* veiled; *pes,* foot; veiled stem).
Mansfield, July.

AMANITOPSIS Roz.

ἀμανῖται, Amanita; ὄψις, appearance; resembling Amanita.

Like *Amanita,* the young plants of *Amanitopsis* are covered with a universal veil, which, when ruptured, leaves remnants upon the surface of the cap and at the base of the stem. The plants of this genus, therefore, possess a volva, or cup, at the base of the stem, but the ring on the upper part of the stem is absent. In this way they are distinguished from *Amanita.* Formerly these plants were included with the Amanitas, but the closely sheathing volva and the absence of a ring, place them in a separate genus. All species of *Amanitopsis* thus far determined are reported edible, but some species so closely resemble poisonous Amanitas that extremely careful examination should be made, to be certain that no trace of a ring is present on the stem.

A. vaginata is the most common species in this vicinity, and is usually found in open woods, growing among the leaf-

PLATE I. *Amanita muscaria*. Fly Amanita. (Reduced one-third.)
becoming pale, whitening when old, covered with thick, angular warts ; ring very

PLATE II. *Amanita phalloides*. Deadly Amanita. (Natural size.)
Cap white, yellowish-brown or blackish-brown, viscid in moist weathe
stem smooth or floccose, bulbous, with a distinct volva, or with a narr
margin on the bulb ; ring near top of stem, entire.

mold. Its characteristic sheathing volva and deeply striate pileus distinguish it from other species. *A. volvata* is also quite abundant.

Ten species of American *Amanitopsis* have been reported. Four are reported in Connecticut.

Amanitopsis farinosa Schw. (mealy).
Mansfield, July (78).

Amanitopsis strangulata (Fr.) Roz. (choked).
East Hartford, Rainbow, *Hanmer.*

Amanitopsis vaginata (Bull.) Roz. (having a sheath).
Mansfield, July, Aug. (147); East Hartford, *Hanmer.*

Amanitopsis vaginata (Bull.) Roz., var. **livida.** Pers. (livid).
Mansfield, July (88).

Amanitopsis volvata (Pk.) Sacc. (having a volva).
Mansfield, July, Aug. (259); Suffield, Sept.

LEPIOTA Fr.

λεπίς, a scale.

This genus is distinguished from *Amanita* and *Amanitopsis,* by the absence of a definite volva. These plants have a more or less persistent ring on the stem, but the volva is not present. The cap is generally scaly from the rupturing of the cuticle and the remains of the veil. The gills are not attached to the stem, but are joined to a cartilaginous collar which surrounds the stem. The substance of the stem is different from that of the cap, and the two are joined in a socket-like manner, so that the cap is easily separated from the stem. The ring in some species is easily movable on the stem when the specimens are mature. Many species are edible.

The Lepiotas are more frequently found in gardens, hotbeds and lawns, than in the woodlands. *L. procera* is sometimes found in thin chestnut sprout-land, or where the timber growth is young. The white spores, absent volva, scaly cap, and somewhat movable ring on the stem easily distinguish this species.

Lepiota Americana Pk.
East Hartford, *Hanmer;* New Haven, *Clinton.* Edible (Pk.).

Lepiota asperula Atk. (slightly rough).
East Hartford, *Hanmer.*

Lepiota clypeolaria Bull. (shield-shaped).
Manchester, *Hanmer.*

Lepiota cristata A. & S. (crested).
South Windsor, *Hanmer;* New Haven, *Clinton;* Mansfield, July (154). Edible (Pk.).

Lepiota farinosa Pk. (mealy).
South Windsor, *Hanmer.* Edible (Pk.).

Lepiota granulosa Batsch. (granular).
South Windsor, *Hanmer.*

Lepiota illinita Fr. (smeared over).
Mansfield, Aug. (231). Edible (McI.).

Lepiota metulæspora B. & Br. (having obelisk-shaped spores).
Mansfield, July, Aug. (214).

Lepiota naucinoides Pk.
East Hartford, *Hanmer.* Edible (Pk.).

Lepiota procera Scop. (tall). Parasol Mushroom.
East Hartford, *Hanmer;* Goshen, *Underwood;* New Haven, *Clinton;* Mansfield, July, Aug. (95). Edible (McI.). Plate III.

ARMILLARIA Fr.

Armilla, a ring.

This is a small genus which closely resembles some species of *Amanita* and *Lepiota,* but differs by having the gills attached to the stem. The substance of the stem and pileus is also similar and continuous, while in the other genera the stem and cap easily separate. In *A. mellea* the cap is honey-colored or somewhat brown with dark scales. The inner veil is present and forms a distinct ring on the stem. Often the plants are found attached to the roots of living trees, and are considered harmful parasites. The plants are clustered, and the bases are connected by a rope-like strand of mycelium.

Armillaria mellea Vahl. (honey-colored).
Goshen, *Underwood;* New Haven, *Clinton;* Mansfield, July (164). Edible (Atk.). Plate IV.

PLATE III. *Lepiota procera.* Parasol Mushroom. (Reduced.)
Cap variable in color, usually some shade of brown, covered with brown scales; stem variable in length, often tall, tubular; ring thick, firm, movable.

PLATE IV. *Armillaria mellea.* Honey-colored Armillaria. (Natural size.)
Cap covered with minute tufts of brown or blackish hairs, sometimes glabrous;
flesh white or whitish.

MARASMIUS Fr.

μαραίνω, to become completely dry.

The species of *Marasmius* are small plants which resemble *Mycena* and *Collybia,* but which differ from these groups in having properties which enable them to revive after drying, if moisture is applied; in many instances they resume their normal form. The cap is tough, thin, and more or less regular in shape. The gills are thin also and pliant. The stem is somewhat brittle and of a different substance from the pileus.

The members of this group are very numerous in the woods and fields, but possess little food value, because they are usually small. Several have a strong flavor of garlic. The species most plentiful during the past season were *M. oreades,* the "fairy-ring mushroom," *M. rotula* and *M. cohærens.* The plants are found on decaying leaves, rotten wood, and on the ground.

Marasmius cohærens (Fr.) Bres. (holding together).
Mansfield, July, Aug. (189).
Synonymous with *Mycena cohærens* Fr., *Collybia lachnophylla* Berk., *Collybia spinulifera* Pk.

Marasmius elongatipes Pk. (long-stemmed).
Mansfield, June (24).

Marasmius oreades Fr. (mountain nymphs). Fairy-Ring Mushroom.
Goshen, *Underwood;* New Haven, *Clinton;* Mansfield, Aug. (210). Edible (Pk.).

Marasmius retiphyllus Atk. (*rete,* net; *phyllon,* leaf; referring to the netted gills).
Mansfield, July, Aug. (205).

Marasmius rotula (Scop.) Fr. (wheel).
Mansfield, June (3).

Marasmius scorodonius Fr. (garlic-smelling).
Mansfield, June, July; Suffield, Aug. (4). Used for flavoring (Cooke).

Marasmius semihirtipes Pk. (having stem half-hairy).
Mansfield, June, July (9).

Marasmius varicosus Fr. (varicose).
Mansfield, June, July (51).

TRICHOLOMA Fr.

θρίξ, a hair; λῶμα, a fringe.

The veil is wholly wanting in most species of *Tricholoma*, therefore the ring and volva on the stem are absent. In some few species a minute veil is manifest by cobwebby down on the margin of the pileus. In this genus the gills are joined to the stem, and are more or less strongly notched at the point of union. The pileus is fleshy, and similar in substance to the short, stout stem.

The species are usually found in moist woodland, growing on the ground among decaying leaves, but occasionally they occur in open pastures. Many are edible, but some few species are said to be poisonous.

Tricholoma albi-flavidum Pk. (yellow-white).
South Windsor, *Hanmer;* Mansfield, July (68).

Tricholoma album Schæff. (white).
Mansfield, July (85). Taste bitter (Pk.).

Tricholoma equestre Linn. (*eques,* knight).
South Windsor, *Hanmer.* Edible (Pk.).

Tricholoma personatum Fr. (masked).
Manchester, *Hanmer.* Edible (Atk.). Plate V.

Tricholoma portentosum Fr. (portentous).
East Hartford, *Hanmer.* Edible (McI.).

Tricholoma rutilans Schæff. (reddish).
South Windsor, *Hanmer;* Mansfield, Aug. (226). Edible (McI.).

Tricholoma sejunctum Sow. (disjoined).
South Glastonbury, *Hanmer.*

Tricholoma transmutans Pk. (changing).
Rainbow, *Hanmer.* Edible (Pk.).

Tricholoma terreum Schæff. (earthen).
Rainbow, *Hanmer.* Edible (Pk.).

COLLYBIA Fr.

κόλλυβος, a coin.

The cap is fleshy and usually thin, and in the young plant the margin is inrolled, thus differing from *Mycena* which this genus resembles.

PLATE V. *Tricholoma personatum.* Masked Tricholoma.
(Natural size, often larger.)
Cap variable in color, generally pallid, tinged with lilac or violet; stem thick, solid, somewhat bulbous.

PLATE VI. *Collybia radicata.* Rooted Collybia. (Reduced.)
Cap variable, usually brown with grayish shades, sometimes almost white, glutinous when moist; flesh thin, white, elastic; stem tapering upward; root extending deeply into earth, tapering, pointed.

The stem is rather brittle on the outside, but is frequently stuffed with fibers within. The ring and volva are wanting from the stem, and the gills are mostly attached to it.

This genus also strongly resembles *Marasmius*, but the plants lack the leathery consistency, and do not revive when once dried.

They are abundant throughout the entire season, growing on stumps, logs, decaying leaves, in soil, in woodlands and open fields.

Many of the fleshy species are desirable for food, and fortunately are abundant and have a long season of growth. Many of the more fleshy species are often infested with larvæ, and need careful examination before preparing for the table. None of the species as yet reported have been found poisonous.

Collybia acervata Fr. (heaped).

East Hartford, *Hanmer;* Mansfield, July (124). Edible (McI.).

Collybia butyracea Bull. (butter-like).

Mansfield, July (64).

Collybia confluens Pers. (flowing together).

Mansfield, July (82).

Collybia dryophila Bull. (oak-loving).

East Hartford, *Hanmer;* Mansfield, July (10).

Collybia esculenta Wulf. (esculent).

East Hartford, July, *Hanmer.* The best edible *Collybia* (Cooke).

Collybia lacerata Lasch. (torn).

East Hartford, *Hanmer.*

Collybia maculata A. & S. (spotted).

East Hartford, Sept., *Hanmer.*

Collybia platyphylla Fr. (πλατύς, broad; φύλλον, leaf; referring to the broad gills).

East Hartford, May, *Hanmer;* New Haven, *Clinton;* Mansfield, June (47). Edible (McI.).

Collybia radicata Relh. (rooted).

East Hartford, Aug., *Hanmer;* New Haven, *Clinton;* Mansfield, July (151). Edible (Curtis). Plate VI.

Collybia strictipes Pk. (short-stemmed).

Mansfield, June (53).

Collybia velutipes Curt. (having a velvety stem).
East Hartford, Sept., *Hanmer;* Mansfield, May (345).
Collybia zonata Pk. (zoned).
Bolton, July, *Hanmer.*

MYCENA Fr.

μύκης, a fungus.

This genus is composed mostly of delicate plants growing on wood, decaying stumps, among decaying leaves, and on the ground.

The cap is more or less conical, and in the immature plant the margin lies flat against the stem, in contrast with the incurved margin of *Collybia.* The stem is frequently long and slender, it snaps easily when bent, and is usually hollow. In some species a colored or watery juice exudes from the stem when it is broken. The gills are attached to the stem. Spores white.

Mycena occurs abundantly in woodlands and occasionally in grasslands. The plants promise little food value because of their small size and thin substance.

Their smallness makes the determination of species rather difficult. A few, however, have characteristic odors which aid in establishing their identity.

Mycena cyanothrix Atk. (blue-haired).
Mansfield, June (26). Plate VII.
Mycena epipterygia Scop. (ἐπί, upon; πτερύγιον, little wing).
Mansfield, July, Aug. (230).
Mycena galericulata Scop. (*galericulum,* a small peaked cap).
Mansfield, June (6).
Mycena hæmatopa Pers. (bloody-stemmed, referring to juice).
Mansfield, July, Aug. (65).
Mycena pelianthina Fr. (πελιός, livid; ἄνθος, flower).
Mansfield, Aug. (261).
Mycena vulgaris Pers. (common).
Mansfield, Aug. (5).

PLATE VII. *Mycena cyanothrix.* Blue-haired Mycena. (Natural size.)
Cap viscid when young, blue, becoming pale and whitish in age, and fuscous in center ; stem clothed with blue hairs at base.

LACTARIUS Fr.

Lac, milk; milk producing.

This group resembles *Russula* in some respects, but is easily distinguished by the abundance of milky juice which exudes from all parts of the plant when it is broken. The cap is rigid, somewhat sunken in the center, and often marked on its surface with concentric zones. The stem is stout, solid, and frequently marked with peculiar blotches. The gills are attached to the stem, and often extend down it in decurrent lines. The species are determined largely by their characteristic coloring, taste, and nature of milk. The colors vary greatly, and the taste in many species is peppery and acrid. These qualities, however, disappear in cooking, and many of the peppery species are classed among esculent mushrooms. The color of the milk in most species is white, but it often changes rapidly when exposed to the air. For example, in *L. theiogalus* the milk quickly changes to a sulphur yellow. In *L. indigo* the color of the milk is a deep indigo blue. These characteristics must be carefully noted when the fresh specimens are collected, otherwise their determination becomes difficult.

Many members of this group are desirable for their food value. The writer has enjoyed many meals of *L. volemus,* and *L. deliciosus. L. corrugis* is said to be equally desirable, but it does not occur in Mansfield in sufficient quantities to be of much value. They are remarkably free from larvæ of all kinds. Nearly all species grow on the ground and occur abundantly. During August of the past season, the woods in the vicinity of Mansfield contained immense quantities of *L. deceptivus. L. volemus* was also plentiful throughout the season.

Lactarius aquifluus Pk. (watery).
South Windsor, *Hanmer.* Edibility uncertain.

Lactarius blennius Fr. (slimy).
South Windsor, *Hanmer.* Edibility uncertain.

Lactarius camphoratus (Bull.) Fr. (having an odor of camphor).
East Hartford, South Windsor, *Hanmer.*

Lactarius chrysorrheus Fr. (flowing with gold).
Mansfield, Aug. (258).

Lactarius corrugis Pk. (wrinkled).
Rockville, *Hanmer;* Goshen, *Underwood;* Mansfield, Aug. (244).

Lactarius chelidonium Pk. (referring to the Celandine, a flowering plant with yellow acrid juice).
Goshen, *Underwood;* Mansfield.

Lactarius deceptivus Pk. (deceitful).
Goshen, *Underwood;* Mansfield, Aug. (319). Plate VIII.

Lactarius deliciosus (L.) Fr. (delicious).
Goshen, *Underwood;* Mansfield, July (298).

Lactarius fuliginosus Fr. (sooty).
Mansfield, Aug. (202).

Lactarius fumosus Pk. (smoky).
Mansfield, July (188).

Lactarius griseus Pk. (gray).
Mansfield, Aug. (198).

Lactarius hygrophoroides B. & C. (resembling *Hygrophorus*).
East Hartford, South Windsor, *Hanmer.*

Lactarius indigo (Schw.) Fr. (blue).
Goshen, *Underwood;* Mansfield, Aug. (321).

Lactarius luteolus Pk. (yellowish).
South Windsor, *Hanmer.*

Lactarius lignyotus Fr. (λιγνύς, a smoke).
East Hartford, *Hanmer.* Edible (McI.).

Lactarius pallidus (Pers.) Fr. (pale).
Manchester, *Hanmer.* Edible (Cooke).

Lactarius pergamenus (Schw.) Fr. (*pergamena,* parchment).
South Windsor, *Hanmer.* Edible (Cooke).

Lactarius piperatus (Scop.) Fr. (peppery).
East Hartford, *Hanmer;* Mansfield, July (90). Plate IX.

Lactarius pyrogalus (Bull.) Fr. (πῦρ, fire; γάλα, milk).
Goshen, *Underwood.*

Lactarius subdulcis (Bull.) Fr. (sweetish).
Goshen, *Underwood;* Mansfield, July (41).

PLATE VIII. *Lactarius deceptivus*. Deceptive Lactarius. (Reduced one-third.)
Cap white or tinged with yellow, slightly tomentose or glabrous, except on the margin, which is at first inrolled and clothed with a dense, soft, woolly covering; gills broad, distant.

PLATE IX. *Lactarius piperatus*. Peppery Lactarius. (Reduced one-third.)
Cap white, funnel-shaped at maturity; gills crowded; milk white, unchangeable, very acrid.

Plate X. *Lactarius volemus.* Orange brown Lactarius. (Reduced one-third.)
Cap golden-tawny or brownish-orange, somewhat depressed at maturity, glabrous; gills close; milk copious, white, slightly acrid.

Lactarius subpurpureus Pk. (purplish).
Goshen, *Underwood.*

Lactarius theiogalus (Bull.) Fr. (θεῖον, brimstone; γάλα, milk).
Goshen, *Underwood;* Mansfield, Aug. (315).

Lactarius torminosus (Schæff.) Fr. (producing gripes).
Goshen, *Underwood.*

Lactarius trivialis Fr. (common).
Goshen, *Underwood;* Mansfield, July (157).

Lactarius vellereus Fr. (fleecy).
Mansfield, July (91).

Lactarius volemus Fr. (*volema,* a large pear).
Goshen, *Underwood;* Mansfield, July (141). Edible (Fr.). Plate X.

RUSSULA Pers.

Russulus, reddish.

The variations in coloring in the species of Russula make their determination difficult, but the distinct generic characteristics seldom allow them to be confused with other genera. The cap is regular, with a more or less prominent depression, and somewhat rigid. The tissue constituting the cap and gills is composed of large cells which easily separate, giving this tissue a more or less mealy appearance when crushed. The stem is short, stout, brittle, very smooth without and spongy within. The veil is wholly lacking, so there are no indications of a ring or volva on the stem. The spores, when viewed under a microscope, are roughened or warty, and are white or of a yellowish tint when collected on a dark surface.

The species of *Russula* resemble closely *Lactarius,* but lack the milky juice. They occur abundantly during the summer, and until the severe frosts of autumn they are found in nearly every woodland. All species grow on the ground. Many species are reported edible, but the one considered the most desirable for food is *R. virescens,* the "green russula."

All edible species must be in a perfectly fresh condition when cooked, or the taste is strong and offensive. Many species have a characteristic taste and some a characteristic odor,

so their identity is revealed at once. When *R. fœtens* is once known it is rarely forgotten, and the strong, acrid taste of *R. emetica* makes a lasting impression on the collector.

Russula aurata (With.) Fr. (*aurum*, gold).
Mansfield, Aug. (305).

Russula adusta (Pers.) Fr. (scorched).
Manchester, *Hanmer*.

Russula atropurpurea Pk. (dark purple).
South Windsor, *Hanmer*.

Russula brevipes Pk. (short-stemmed).
Bolton, *Hanmer*.

Russula citrina Gillet (citron-colored).
Mansfield, July (115).

Russula compacta Frost (close-grained).
South Windsor, *Hanmer*.

Russula depallens Fr. (becoming pallid).
Mansfield, July (72).

Russula flavida Pk. (yellow).
Rockville, *Hanmer*.

Russula fœtens (Pers.) Fr. (stinking).
Mansfield, July, Aug. (172). Plate XI.

Russula furcata (Pers.) Fr. (forked).
Mansfield, July (141).

Russula lepida Fr. (elegant).
Mansfield, Aug. (313).

Russula roseipes (Secr.) Bres. (red-stemmed).
Mansfield, Aug. (328).

Russula sanguinea (Bull.) Fr. (blood-red).
Mansfield, July (77).

Russula virescens (Schæff.) Fr. (becoming green).
Mansfield, July (35). Edible (Pk.).

PLEUROTUS Fr.

πλευρά, a rib.

The pileus, or cap, is irregular, more or less fleshy, and in some species becomes membranaceous but never woody. The stem is fleshy and of the same consistency as the pileus; in many species it is not distinct from it. The stem is attached

PLATE XI. *Russula fœtens.* Stinking Russula. (Reduced one-third.)
Cap dingy yellow, becoming pale, viscid in moist weather, margin deeply striate ; stem stout, stuffed, then hollow ; taste acrid.

Plate XII. *Pleurotus ostreatus.* Oyster Pleurotus. (Natural size, often larger.)
Cap white to dark gray, often yellowish at maturity ; gills extending down the stem, connected by veins.

at one side of the center, at one edge of the pileus, or in some species it is lacking; the pileus being then attached directly to the substratum.

When the stem is present, the gills usually extend down it for a greater or less distance.

This group is usually found growing on wood either dead or alive. It contains many edible species. The well known oyster pleurotus and elm pleurotus are among the most desirable of these species. As in *Collybia,* these mushrooms are very frequently infested with larvæ.

Pleurotus lignatilis Fr. (woody).
Mansfield, July (81).

Pleurotus ostreatus Jacq. (oyster-like).
East Hartford, *Hanmer;* Mansfield, Aug. (217). Edible (Pk.). Plate XII.

Pleurotus petaloides Bull. (like a petal of a flower).
Mansfield, July (158). Edible (Cooke).

Pleurotus sapidus Kalchb. (savory).
South Windsor, *Hanmer;* Mansfield, Nov. (366). Edible (Pk.).

Pleurotus serotinus Schr. (late).
South Windsor, *Hanmer.*

Pleurotus ulmarius Bull. (pertaining to the elm).
East Hartford, *Hanmer.* Edible (Atk.).

NYCTALIS Fr.

νύξ, night; from inhabiting dark places.

This is a small genus of mushrooms, but interesting from the fact that the only American species is found living upon decaying mushrooms of other genera. Some of the species of *Russula* seem the most frequent host-plant. The cap is white or grayish white, fleshy; stem short; gills blunt, distinct, thick, and juicy.

Nyctalis asterophora Fr. (star-bearing; from the star-shaped bodies in the dust on the pileus).
South Windsor, *Hanmer;* Goshen, *Underwood.*

HYGROPHORUS Fr.

ὑγρός, moist; φορέω, to bear.

This genus includes many species which are highly colored and quickly attract the eye of the amateur collector, but the species, as a rule, are difficult for the beginner to determine.

The plants must be studied while fresh, for many distinguishing characters disappear upon drying. The pileus is rather fleshy and generally moist or viscid. The gills are, perhaps, the most distinguishing feature about this group of plants. They are very sharp or acute at the edges and are gradually thickened as they approach the pileus, making a distinct V-shaped appearance when a cross section is made. They also have a peculiar, watery appearance, and are of a waxy consistency. Usually the gills are attached to the stem and extend down it in decurrent lines, frequently branching considerably.

Hygrophorus caprinus (Scop.) Fr. (*caper*, goat).
Mansfield, Aug. (274.)

Hygrophorus calophyllus Karst. (having beautiful leaves).
Rainbow, *Hanmer.*

Hygrophorus ceraceus (Wulf.) Fr. (waxy).
Rainbow, *Hanmer;* Mansfield, Aug. (254).

Hygrophorus chlorophanus Fr. (greenish yellow).
Mansfield, June (23).

Hygrophorus conicus (Scop.) Fr. (conical).
Mansfield, July (130). Plate XIII.

Hygrophorus coccineus (Schæff.) Fr. (scarlet).
Rainbow, *Hanmer.* Edible (Cooke, Pk.).

Hygrophorus erubescens Fr. (becoming red).
Rainbow, *Hanmer.* Edible (Cooke).

Hygrophorus Lauræ Morgan.
Manchester, *Hanmer.*

Hygrophorus miniatus Fr. (red).
Mansfield, June (35). Edible (Pk.).

Hygrophorus miniatus Fr. var. **lutescens** (yellowish).
Mansfield, July (109).

Hygrophorus nitidus B. & C. (shining).
Mansfield, July (175). Edible (McI.).

PLATE XIII. *Hygrophorus conicus.* Conical Hygrophorus. (Natural size.)

Cap conical, acute, often lobed, yellow or tinged with crimson.

PLATE XIV. *Cantharellus cibarius.* Chantarelle. (Natural size)
Cap egg-yellow, slightly depressed, fleshy ; gills thick, distant, more or less branching.

PLATE XX. *Cantharellus infundibuliformis.* Funnel-form Cantharellus. (Natural size.) Cap smoky yellow at first, then pale yellow, floccose; gills thick, dichotomously branched; stem glabrous, yellow.

Hygrophorus pratensis (Pers.) Fr. (pertaining to a meadow).
Mansfield, July (108). Edible (Cooke).
Hygrophorus puniceus Fr. (purplish red).
East Windsor, *Hanmer*. Edible (Cooke).
Hygrophorus virgineus (Wulf.) Fr. (*virgo*, a virgin).
Rainbow, *Hanmer*. Edible (Cooke).

CANTHARELLUS Adanson.

Cantharus, a cup; from form of cap.

The members of this genus are more or less funnel-shaped at maturity, or at least quite deeply depressed in the center. The pileus is fleshy with a rather thick, blunt margin. The characteristic feature of the genus is the blunt gills, which are usually narrow, and in many species they resemble veins or wrinkles. They frequently branch and join by net-like veins. The number of Connecticut species is not large, and their characteristic features are so distinct that their identification is not as difficult as in many genera. Several are considered excellent for the table. *Cantharellus cibarius* is thought the most desirable species. It is widely distributed and is found abundantly.

Cantharellus brevipes Pk. (short-stemmed).
Rainbow, *Hanmer*. Edible (McI.).
Cantharellus cibarius Fr. (edible).
Mansfield, Aug. (218). Edible (Pk.). Plate XIV.
Cantharellus cinnabarinus Schw. (having the color of dragon's-blood).
Goshen, *Underwood;* Mansfield, July (232).
Cantharellus dichotomus Pk. (dividing by pairs).
East Hartford, *Hanmer*.
Cantharellus floccosus Schw. (woolly).
Mansfield, Aug. (224).
Cantharellus infundibuliformis (Scop.) Fr. (funnel-form).
Mansfield, Aug. (94). Plate XV.
Cantharellus lutescens Fr. (yellowish).
Manchester, *Hanmer*.

Cantharellus rosellus Pk. (rosy).
South Windsor, *Hanmer.*

OMPHALIA Fr.

ὀμφαλός, navel.

These plants strongly resemble *Mycena* and *Collybia,* but differ from them by having a brittle stem, with the gills running down it, and by the pileus being more or less depressed in the center, frequently becoming funnel-form. They are usually found growing on wood, especially rotten stumps in swamps and damp localities. The most common species in eastern Connecticut is *O. campanella,* which occurs in immense numbers. The specimens photographed for illustration grew on a rotten stump in a swamp in Mansfield. This is the only species thus far reported in Connecticut.

Omphalia campanella Batsch. (bell-shaped).
East Hartford, *Hanmer;* Mansfield, Aug. (134). Plate XVI.

CLITOCYBE Fr.

κλιτύς, slope; κυβή, head.

This group contains a large number of species whose individual characteristics vary so much that their identification is puzzling even to the experienced collector. It belongs to the white-spored series of Agaricaceæ, and in all species the ring and volva are absent. The pileus is generally fleshy, thicker in the center and narrowed toward the margin. The stem is similar to the pileus in consistency, is somewhat hollow, and is held by fibers on the outside so that it does not break easily when twisted or bent.

The gills are joined squarely to the stem (adnate), or in many species extend down the stem (decurrent). They occur usually growing on the ground, and frequently are found in large groups. *C. illudens* is often found grouped in large numbers about the bases of stumps of old trees, and *C. odora* is equally abundant in decaying leaves. This latter species is interesting because of its fragrance, which resembles that of water-lilies.

PLATE XVI. *Omphalia campanella.* Bell-shaped Omphalia. (Natural size.)
Cap thin, rusty yellow, striate ; stem hollow, brown.

PLATE XVII. *Clitocybe odora.* Fragrant Clitocybe. (Natural size.)
Cap pale dingy green.

Plate XVIII. *Clitocybe illudens*. Phosphorescent Clitocybe. (Reduced one-third.)
Cap fleshy, convex, smooth, deep yellow; gills unequally decurrent.

PLATE XIX. *Clitocybe infundibuliformis.* Funnel-form Clitocybe. (Reduced one-third.) Cap pale-red, tinged with buff, sometimes becoming pale with age; gills close, thin, whitish; stem usually tapering from base upward.

Clitocybe amethystina Bolt. (amethystine).
East Hartford, Manchester, *Hanmer.*

Clitocybe clavipes Pers. (club-footed).
East Hartford, *Hanmer.*

Clitocybe odora Bull. (fragrant).
Mansfield, Aug. (275). Plate XVII.

Clitocybe illudens Sch. (mocking).
Mansfield, July (159). Not edible (Atk.). Plate XVIII.

Clitocybe infundibuliformis Sch. (funnel-form).
Mansfield, Aug. (197). Plate XIX.

Clitocybe ochro-purpurea Berk. (ochreous purple).
Mansfield, Aug. (326).

Clitocybe trullissata Ellis. (scoop-shaped).
East Hartford, *Hanmer.*

Clitocybe laccata Scop. (made of lac, a resinous substance).
Mansfield, June (77).
Synonymous with *Laccaria laccata.*

LENZITES.

After Lenz, a German botanist.

In *Lenzites,* the substance of the pileus is leathery and corky. It is usually horizontal, more or less zoned, and resembles several genera belonging to the Polyporaceæ, with which it is commonly classed. The gills are leathery and tough, unequal, simple or branched. All species grow on wood.

Lenzites betulina (L.) Fr. (pertaining to the birch).
East Hartford, *Hanmer;* Goshen, *Underwood;* New Haven, *Clinton.*

Lenzites flaccida (Bull.) Fr. (flaccid).
East Hartford, *Hanmer;* Mansfield, Feb. (342).

Lenzites sepiaria Fr. (*sepes,* a fence or hedge).
= **Sesia hirsuta** (Schæff.) Murrill.
South Windsor, *Hanmer;* New Haven, *Clinton.*

Lenzites vialis Pk. (roadside).
= **Sesia pallido-fulva** (Berk.) Murrill.
Goshen, *Underwood.*

LENTINUS Fr.

Lentus, tough or pliant.

The pileus, or cap, of these plants is fleshy and leathery in consistency, becoming very tough and hard at maturity. The gills are of the same general character, and thin on the margins, which are toothed. The gills extend down the stem in more or less decurrent lines.

The stem in the different species is attached in various ways to the pileus. It may be central, or attached at one side of the center (eccentric), or it may be attached at one edge of the pileus (lateral), giving it a shelving appearance. Several species are exceedingly injurious to wood; the mycelium, or vegetative portion of the plant, inhabits the woody tissue, and in many different ways brings about destruction of the cell structure, causing decay. *L. lepideus* is usually found on railroad ties and is destructive to them.

Lentinus chrysopeplus B. & C. (golden-cloaked).
Mansfield, June (52).

Lentinus Lecomtei Fr.
Mansfield, June (1).

Lentinus lepideus Fr. (scaly).
East Hartford, *Hanmer;* Mansfield, July (238).

Lentinus tigrinus (Bull.) Fr. (tiger-spotted).
East Hartford, *Hanmer.*

Lentinus vulpinus Fr. (hairy like a fox).
Mansfield, July (237).

PANUS Fr.

The name of a fungus growing on trees, described by Pliny.

This group very closely resembles *Lentinus,* and by many authors the species are classed in that genus. The general characters are the same, but the margins of the gills are entire, thus differing from the toothed margins of the gills of *Lentinus.*

Panus farinaceus Schum. (mealy).
East Hartford, *Hanmer.*

Panus rudis Fr. (rough).
South Windsor, *Hanmer.*

Panus stipticus (Bull.) Fr. (astringent).
Mansfield, Aug. (220).

Panus salicinus Pk. (pertaining to the willow).
New Haven, *Clinton.*

Panus torulosus Fr. (*torulus,* a tuft of hair).
Mansfield, June (21).

SCHIZOPHYLLUM Fr.

σχίζω, to split; φύλλον, a leaf; referring to the split gills.

This group is separated easily from the other white-spored Agarics by the peculiar split gills, their dense, white, woolly covering, and general revolute appearance. Only one species is found in this locality. The appearance of the plant, especially when growing in abundance upon a log, is very attractive, and once learned it is rarely forgotten. The pileus is small, thin, and covered with a dense, hairy coat. It is variously attached to the substratum, generally at the side (lateral), or it may be attached at or near the center of the top. If collected during the winter months and placed under a bell-jar in a warm room, the pileus quickly expands.

Schizophyllum commune Fr. (common).
Mansfield, Oct. (203).
Synonymous with *Schizophyllum alneum* Schr.

TROGIA Fr.

After Trog, a Swiss botanist.

This small genus contains but one species reported from Connecticut. It is commonly found on decaying logs and branches, and is distinguished by the characteristic vein-like gills, which are somewhat curled.

Trogia crispa (Pers.) Fr. (crisped or curled).
Goshen, *Underwood;* Mansfield (225).

PAXILLUS Fr.

Paxillus, a small stake.

In *Paxillus,* the gills and pileus are easily separable, and the gills are so intricately connected by veins that many of the species closely resemble those in Polyporaceæ.

When the stem is present, the gills usually extend down it (decurrent), and the edges are entire and acute. The pileus is fleshy, inrolled in the immature specimens, and more or less viscid on the surface. The spores are ochre-colored. These plants are found singly or in tufts, growing on wood or on the ground.

Paxillus aurantiacus Ellis (orange-colored).

Mansfield, July (234).

Paxillus atro-tomentosus (Batsch) Fr. (having black down).

South Windsor, Rainbow, *Hanmer*.

Paxillus involutus (Batsch) Fr. (involute).

Mansfield, July (118). Edible.

Paxillus panuoides Fr.

East Hartford, *Hanmer;* Mansfield, July (200).

CORTINARIUS Fr.

Cortina, a veil.

This genus contains plants puzzling to the amateur collector, and difficult of determination even by the more experienced. Because of the peculiar nature of the plant it is necessary to have specimens in all stages of development, otherwise the identification is almost impossible. When young, the plants are covered with a cobwebby veil which is distinct from the cuticle of the cap, but in the more mature specimens this veil entirely disappears, except in some species where a fragile ring is perceptible upon the stem, or minute particles may be seen on the surface and margin of the pileus. The plants are mostly fleshy throughout, and are variously colored; many have beautiful violet tints, but the majority are yellow or brown.

The gills in the mature specimens are usually densely powdered with spores. The number of species is large, and many are found only in the fall, for they seem adapted to a cooler season of the year, although some are found during the early summer.

The specimens collected by Mr. C. C. Hanmer and the writer were sent to Mr. C. H. Kauffman of the Department of Botany, Ann Arbor, Michigan, for identification. Mr. Kauff-

PLATE XX *Cortinarius cinnamomeus* var. ***semi-sanguineus.*** Cinnamon-colored Cortinarius (Reduced one-third.)
Cap cinnamon-color, covered with fibrils when young, glabrous when mature.

man has made a special study of this genus, and his opinion regarding the accuracy of determination of species is valuable.

Cortinarius armillatus Fr. (ringed).
Rainbow, *Hanmer.*

Cortinarius bolaris (Pers.) Fr. (*bolus,* a clod of red clay; allusion to color).
Mansfield, Aug. (308).

Cortinarius collinitus (Pers.) Fr. (besmeared; referring to glutinous surface).
Hartford, *Hanmer;* Mansfield, Aug. (184).

Cortinarius corrugatus Pk. (corrugated).
East Hartford, South Windsor, Rainbow, *Hanmer;* Mansfield, Aug. (285).

Cortinarius cinnabarinus Fr. (having the color of dragon's blood).
Mansfield, July (136).

Cortinarius cinnamomeus (L.) Fr. (cinnamon-colored) var. **semi-sanguineus.**
East Hartford, South Windsor, *Hanmer;* Mansfield, July. Plate XX.

Cortinarius iodes B. & C. (violet).
East Hartford, *Hanmer.*

Cortinarius lilacinus Pk. (lilac-colored).
Mansfield, Aug. (178).

Cortinarius turbinatus (Bull.) Fr. (top-shaped).
Rockville, *Hanmer.*

PHOLIOTA Fr.

φολίς, a scale.

The members of the genus Pholiota are fleshy both in cap and stem, and the substance of the two is similar. The volva, or cup, is absent from the base of the stem, but a distinct ring is persistent near the top, and in immature specimens the gills are covered by the partial veil. The color of the spores serves to separate the genus from *Armillaria* of the white-spored group and *Stropharia* of the brown-spored group. The spores of *Pholiota* are a rusty-red with a yellow tinge when collected in quantity, and in some species are light red.

The gills are closely joined to the stem, and are often rusty-brown in mature specimens because of an accumulation of spores upon them. They resemble some of the species of *Cortinarius* of this same group, but the ring is stouter and more persistent. The species of *Cortinarius* have a fine cobweb-like veil surrounding the immature plants, which ruptures with growth, often leaving a delicate ring on the stem, which quickly disappears.

Pholiotas are found on tree trunks, old stumps, decaying wood of all kinds, as well as on the ground. Several are edible, and the writer has found *Pholiota squarrosoides* to have an especially fine flavor. Several species which have been tested have been found bitter and tough.

Pholiota æruginosa Pk. (*ærugo,* verdigris).
East Hartford, *Hanmer.*

Pholiota curvipes Fr. (curve-stemmed).
Mansfield, July (45).

Pholiota caperata Pers. (wrinkled).
East Hartford, *Hanmer.*

Pholiota præcox Pers. (early).
East Hartford, *Hanmer;* Mansfield, June (15).

Pholiota squarrosa Müll. (scurfy).
East Hartford, *Hanmer;* New Haven, *Clinton.* Edible (Curtis).

Pholiota squarrosoides Pk. (resembling the species *squarrosa*).
Mansfield, Aug. (269). Edible (McI.). Plate XXI.

CREPIDOTUS Fr.

κρηπίς, a boot.

The species of this genus are usually found growing on decaying stumps and fallen logs in woodland swamps and other damp, shady places. In their habit of growth and general appearance they strongly resemble *Pleurotus,* but are usually smaller and differ in the ochre color of the spores.

Crepidotus applanatus Pers. (made level).
Mansfield, July (146).

PLATE XXI. *Pholiota squarrosoides*. Viscid-scurfy Pholiota. (Natural size.)
Cap fleshy, viscid when moist, densely covered with erect, tawny scales; gills white at first, then cinnamon color; ring thick, floccose; stem rough with thick scurfy scales.

PLATE XXII. *Crepidotus malachius.* (Natural size.)
Cap gray ; stem short.

Crepidotus crocophyllus Berk. (κρόκος, saffron; φύλλον, leaf; referring to color of gills).
Mansfield, July (127).

Crepidotus malachius B. & C. (mallow-colored).
Mansfield, Aug. (96). Plate XXII.

Crepidotus dorsalus Pk. (*dorsum,* back).
Mansfield, July (126).

BOLBITIUS Fr.

βόλβιτον, dung; referring to place of growth.

This small genus is interesting because of a peculiarity of the gills, which dissolve as the plant reaches maturity, but do not deliquesce into a watery substance, as do the species of *Coprinus.* The cap is fragile, yellowish in color, and usually very mucilaginous in consistency, especially in moist weather.

As the generic name signifies, these plants usually grow on dung, but are sometimes found growing on decaying leaves. *B. variicolor* was found abundantly under shrubs which had been heavily manured the previous fall.

The spores are of a rusty-red color, and collect in large numbers upon the mature gills. But two species are reported.

Bolbitius fragilis (L.) Fr. (fragile).
East Hartford, *Hanmer.*

Bolbitius variicolor Atk. (variously colored).
Mansfield, May (22).

INOCYBE Fr.

ἴς, fiber; κυβή, head; fibrous cap.

The surface of the cap of the plants in this genus is more or less thickly coated with fine hairs or fibrils, the remnants of a universal veil. The gills are joined to the stem by a small, abrupt curve, but in some species they are joined squarely to the stem, and they may also extend down it, thus becoming decurrent. Only one number was identified during the past season.

Inocybe lanuginosa Bull. (downy).
Mansfield, July (133).

FLAMMULA Fr.

Flamma, a flame.

The generic name of this group signifies the brilliant coloring of the pileus of many of the species. The plants are fleshy throughout, and the gills are variously attached to the stem, but are never free from it. The spores are yellow with a brown tinge. The majority of these plants grow on wood, but a few are found on the ground.

Flammula alnicola Fr. (inhabiting alders).
East Hartford, *Hanmer.*
Flammula flavida Pers. (light yellow).
East Hartford, *Hanmer.*
Flammula fusus Batsch. (spindle-shaped).
Mansfield, July (196).
Flammula hybrida Fr. (hybrid).
South Windsor, *Hanmer.*
Flammula magna Pk. (large).
East Hartford, *Hanmer.*

NAUCORIA Fr.

Naucum, a nut-shell.

The Naucorias are small plants with a more or less fleshy cap, which is cone-shaped or convex when young, becoming expanded when old. The margin of the young cap is always rolled, which distinguishes the genus from *Galera.* The gills are usually free from the stem, but in some few species are attached, though they never run down it. *N. semi-orbicularis* is the only species yet reported, and grows abundantly on the lawns in this vicinity. The spores are of a brown rust color. In form *N. semi-orbicularis* closely resembles *Stropharia semiglobata* of the brown-spored group; but, aside from the difference in color of the spores, the ring on the stem of *S. semiglobata* distinguishes it.

Naucoria semi-orbicularis Bull. (half-round).
East Hartford, *Hanmer;* Mansfield, June. Edible (Atk.).

GALERA Fr.

Galerus, a cap.

The cap, or pileus, is more or less membranaceous in character, and resembles *Mycena* of the white-spored group. When young the margin of the pileus lies flat against the stem, and is not incurved as in *Naucoria.* The stem is brittle, hollow, and fragile. Two of the few species were collected.

Galera hypnorum Batsch. (*hypnum,* moss).
Mansfield, *Thom.*

Galera tenera Schæff. (tender).
Mansfield, June (16).

VOLVARIA Fr.

Volva, a wrapper.

The plants of this genus somewhat resemble *Amanita* of the white-spored group. When the plants are young, they are covered by a universal veil which bursts as the plants develop, leaving a distinct, persistent volva, or cup, at the base of the stem. The stem separates easily from the pileus, and the gills are not attached to the stem. Growing on stumps commonly, sometimes in soil. Ring entirely absent.

Volvaria bombycina (Pers.) Fr. (silken).
East Hartford, *Hanmer.* Edible (Curtis).

PLUTEUS Fr.

Pluteus, a shield; from conical shape of the pileus.

The relationship between this genus and *Volvaria* is very marked. They resemble each other in all respects except the volva. The species are generally found growing on decaying logs or stumps of trees. *P. cervinus* is plentiful throughout the season, and somewhat resembles *Collybia platyphylla* in habit of growth and coloring; but in *P. cervinus* the gills are closer together, and the plant lacks the general coarseness which is characteristic of *C. platyphylla.*

P. cervinus is edible; but, like many of the fleshy forms, is frequently infested by larvæ, and needs careful examination before being prepared for the table. This species varies con-

siderably in general characters; some writers recognize several distinct varieties.

Pluteus admirabilis Pk. (admirable).
Mansfield, July (116). Edible (McI.).

Pluteus cervinus Schæff. (*cervus*, a deer).
Mansfield, July (20, 225). Edible (McI.). Plate XXIII.

Pluteus cervinus Schæff. var. **albipes** (white-stemmed).
South Windsor, *Hanmer*.

Pluteus umbrosus Pers. (shady; from the dark color).
South Windsor, *Hanmer*.

LEPTONIA Fr.

λεπτός, slender.

The Leptonias are generally found growing on the ground in dry pastures, but may be found in mossy swamps, and are distinguished by their slender habit of growth, thin pileus depressed in the center, margin inrolled when the plant is young, and the brittle character of the stem.

They belong to the rosy-spored group, and many species are brilliantly colored.

Leptonia formosa Fr. (handsome).
Mansfield, July (145).

ENTOLOMA Fr.

ἐντός, within; λῶμα, a fringe.

This genus is a suspicious one as regards poisonous characters, and the species should not be collected and eaten indiscriminately. The fungi are fleshy throughout, the volva and ring are absent from the stem, and in many other respects the species resemble *Tricholoma*. The color of the spores when collected in quantity serves, however, to identify the genus as belonging to the rosy-spored group. The spores when examined under a microscope are distinctly angular. The gills are attached to the stem by a sudden curve (sinuate), which fact separates this genus from the other rosy-spored genera. The determination of species is difficult even for the experienced

PLATE XXIII. *Pluteus cervinus*. Fawn-colored Pluteus. (Reduced one-third.)
Cap light gray, yellowish or grayish brown; gills broad, somewhat crowded; spores rose-colored.

collector, and careful notes need to be made regarding the color and viscidity of the cap, and other evanescent characters of the plant, before accurate determination is possible.

Entoloma grande Pk. (large).
Mansfield, July (162).

Entoloma Grayanum Pk.
Mansfield, July (161).

Entoloma rhodopolium Fr. (rosy-gray).
South Windsor, *Hanmer.*

Entoloma strictius Pk. (constricted).
South Windsor, *Hanmer;* Mansfield, July (58).

CLITOPILUS Fr.

κλιτύς, declivity; πῖλος, cap; referring to the depression in cap.

The cap in *Clitopilus* is usually depressed, and in this respect resembles *Eccilia,* but the stem is less brittle, being more fleshy and fibrous in substance.

The species grow on the ground. McIlvaine says, "Some of the best of edible kinds are within this genus; a few are unpleasant raw, none poisonous." The attachment of the gills to the stem should be carefully noted, so that the genus be not confused with *Entoloma* of this same rosy-spored group. In the latter genus the gills are sinuate, and in *Clitopilus* they are more or less squarely joined to the stem or run down it.

Clitopilus abortivus B. & C. (abortive).
New Haven, *Clinton.*

Clitopilus micropus Pk. (short-stemmed).
East Hartford, *Hanmer.*

Clitopilus noveboracensis Pk. (New York Clitopilus) var. **tomentosipes** Pk. (downy-stemmed).
East Hartford, *Hanmer.*

Clitopilus noveboracensis Pk. var. **umbilicatus** Pk.
East Hartford, *Hanmer.*

Clitopilus Orcella Bull.
Mansfield, Aug. (216). Edible (McI.).

Clitopilus popinalis Fr. (belonging to a cook-shop; referring to its edible qualities).
Mansfield, Aug. (262).

Clitopilus tardus Pk. (late).
East Hartford, Jan., greenhouse, *Hanmer.*

Clitopilus unitinctus Pk. (one-colored).
East Hartford, *Hanmer.*

ECCILIA Fr.

ἔγκοιλος, hollowed out.

This small genus has characters similar to those of *Omphalia* of the white-spored group. The pileus is depressed in the center, and when young the margin is inrolled. The stem is brittle as in *Entoloma,* but the gills differ by extending down the stem (decurrent).

Eccilia carneo-grisea B. and Br. (grayish flesh-colored).
East Hartford, *Hanmer.*

AGARICUS Linn.

'Αγαρικόν, a name for a fungus.

This genus is one of the most interesting in the Agaricaceæ because of the economic importance of many of the species. It contains some of the best known species, and their marked characters prevent their being confused with poisonous or harmful mushrooms. The entire plant is more or less fleshy, and the stem has a distinct ring; in some species it disappears as the plant matures, but in the young plant it is quite distinct, and is formed by the rupturing of the veil, which at first encloses the gills. The gills are free from the stem, which easily distinguishes the genus from *Stropharia,* and the abundance of brown spores which are formed on the under surface of the gills in mature plants, together with the presence of a ring upon the stem, prevent its confusion with other genera. The species strongly resemble some of the Lepiotas of the white-spored group. As far as known, no species are poisonous. *A. campestris* occurs in considerable quantities in the vicinity of Mansfield, and its long season of growth makes it a valuable species. It is one of the most familiar species, and nearly every one, even the most inexperienced collector, is familiar with "those toadstools which are pink or brown on the under side." This common field or pas-

PLATE XXIV. *Agaricus campestris.* Field Mushroom **Edible Mushroom.**
(Natural size.)
Cap white, light or dark gray, smooth or silky floccose ; **gills at first pink, then dark brown** ; ring often disappearing in mature specimens ; **spores brown.**

ture mushroom varies much in its size and coloring, but the principal distinguishing characters remain the same. This is the species ordinarily cultivated. All members of the genus grow on the ground, and by far the larger number grow in open, cultivated fields or meadows, but some are found in the woods.

Agaricus abruptus Pk. (abrupt, referring to the abrupt termination of stem).
Manchester, *Hanmer;* Mansfield, Aug. (201).

Agaricus arvensis Schæff. (belonging to cultivated ground). Plowed-land Mushroom. Edible (Pk.).
East Hartford, *Hanmer.*

Agaricus campestris L. (*campus,* a field).
New Haven, *Clinton;* Mansfield, Aug. Edible. Plate XXIV.

Agaricus placomyces Pk. (a flat fungus).
East Hartford, *Hanmer.* Edible (Miller).

Agaricus Rodmanii Pk.
East Hartford, *Hanmer.* Edible (Pk).

STROPHARIA Fr.

στρόφιον, a belt; referring to the ring.

This genus is separated from *Agaricus* by the attachment of the gills to the stem. When young the plants are covered by a partial veil, which leaves a distinct ring on the stem when it bursts. The cap and stem are fleshy, and the plants are considered edible by some writers and poisonous by others. Growing on the ground or on dung.

Stropharia semi-globata Batsch. (hemispherical).
Mansfield, June (13).

Stropharia stercoraria Fr. (pertaining to dung).
East Hartford, *Hanmer.*

HYPHOLOMA Fr.

ὕφος, a web; *λῶμα,* a fringe.

Hypholoma is quite easily separated from the other genera of the brown-spored group, by the veil which covers the gills

in the young specimens, the remnants of which remain attached to the margin of the cap in the matured plants. The whole plant has a fleshy consistency, and many species are edible. The plants are found more abundantly as winter approaches, and the writer has collected them during November after the most severe frosts. The plants grow singly or in groups, but more frequently they are thickly clustered on the surface of decaying logs or stumps.

Hypholoma appendiculatum Bull. (provided with a small appendage).
Mansfield, June (2).

Hypholoma fasciculare Huds. (*fasciculus*, a small bundle).
North Bloomfield, *Hanmer*.

Hypholoma perplexum Pk. (perplexing).
East Hartford, *Hanmer*.

Hypholoma sublateritium Schæff. (almost brick-colored).
Mansfield, Oct. Plate XXV.

Hypholoma rugocephalum Atk. (having a wrinkled head).
Rainbow, *Hanmer*.

PSILOCYBE Fr.

ψιλός, naked; κυβή, head.

This small genus is distinguished by the absence of the veil which occurs in the other genera of the brown-spored group. In the young plants, the margins of the pileus are inrolled. The stem is more cartilaginous than in other genera.

Psilocybe fœnisecii Pers. (*fœnisicia*, mown hay).
East Hartford, *Hanmer*.

COPRINUS Pers.

κόπρος, dung; referring to the place of growth.

The distinguishing characters of this genus are so evident that the plants cannot be confounded with other genera, even by the most inexperienced collector. The plants are common on lawns and on decaying manure, but are sometimes found on decaying stumps and logs. The caps spring up quickly and disappear just as rapidly. Some of the more fragile spe-

PLATE XXV. *Hypholoma sublateritium.* Brick-top Hypholoma. (Natural size, often larger.)
Cap brick-red or tawny; stem floccose-scaly.

PLATE XXVI. *Coprinus comatus*. Shaggy-mane Mushroom.
(Natural size.)

Cap white, covered with shaggy scales, oblong when young, expanding when mature; gills at first white, then tinged with pink, finally dark purple or black; spores black. Plant deliquescing at maturity.

cies last for only a very short time. Several times during collecting trips, species of this genus have been gathered, and before reaching the laboratory they have almost entirely dissolved into a black fluid. This fluid is colored by the abundance of inky-black spores which are formed on the mature gills.

The plants vary from minute forms found on manure heaps to the "shaggy mane" which often grows to a considerable size. The species are usually clustered and occur in considerable quantities where found.

In July of the past summer, the writer found a very rotten maple stump with several large clumps of *C. atramentarius* growing at its base. Knocking the stump to pieces the interior was found crowded with well developed caps. These were cooked and were very tender and deliciously flavored. The plants mature so quickly, especially in moist weather, that it is necessary to keep a careful watch for them if they are to be gathered while fresh.

Coprinus atramentarius (Bull.) Fr. (inky).
Mansfield, July. Edible (Atk.).

Coprinus comatus Fr. (hairy).
East Hartford, *Hanmer;* New Haven, *Clinton.* Edible (Atk.). Plate XXVI.

Coprinus micaceus (Bull.) Fr. (granular).
Mansfield, Aug. (314). Edible (McI.).

Coprinus plicatilis Fr. (folded).
East Hartford, *Hanmer.*

GOMPHIDIUS Fr.

γόμφος, a peg.

Gomphidius includes a small number of species which possess marked characteristics. The color of the spores, however, is often misleading. Atkinson says, "The spores in some species are blackish, and for this reason the genus has been placed by many with the black-spored Agarics, while its true relationship is probably with the genus *Hygrophorus* or *Paxillus.*"

When the plants are young, they are covered by a gluti-

nous, universal veil, which gives them a slimy appearance. The gills are soft and mucilaginous in consistency, and extend down the stem, prominently decurrent. But one species is reported.

Gomphidius rhodoxanthus Schw. (yellowish-red).
South Windsor, *Hanmer.*

PSATHYRELLA Fr.

ψαθυρός, fragile.

In *Psathyrella* the pileus is very thin, membranaceous and striate. The gills are not spotted as in *Panæolus* and *Anellaria,* and at maturity become black by the accumulation of spores upon their surface. *P. disseminata* was found in immense quantities in the greenhouses of A. N. Pierson at Cromwell, Connecticut.

Psathyrella disseminata Pers. (*dissemino,* to scatter; widely spread).
Cromwell, March.

ANELLARIA Karst.

Anellus, a little ring.

The relationship between this genus and *Panæolus* is very close, but in the latter genus the ring is wanting, while in *Anellaria* it is either persistently present or forms a zone around the stem.

Anellaria separata (L.) Karst. (distinct, separate).
East Hartford, *Hanmer.*

PANÆOLUS Fr.

παναίολος, variegated.

This genus has distinct characters, and when once determined it is not easily confused with other genera. It lacks the dissolving qualities of *Coprinus* and the ringed stem of *Anellaria,* but possesses a veil which often remains on the margin of the pileus. McIlvaine says, "*Panæolus* in its entirety has a precise-looking membership. If the gills were cut from cardboard and fixed by machinery, they could not be more

PLATE XXVII. *Panæolus solidipes.* Solid-stemmed Panæolus. (Reduced one-third.)
Cap white ; stem smooth, white, solid ; spores very black.

correct. Some of the species are among the earliest arrivals at toadstool lawn parties, and some are the last to leave."

During the past season *P. retirugus* was exceedingly abundant in the flower beds on the campus at the Connecticut Agricultural College, and could be collected almost any day throughout the entire season. *P. solidipes* is an attractive looking plant. Its large size, pure white color, and symmetrical shape give it a pleasing individuality.

Panæolus campanulatus Linn. (bell-shape).
Mansfield, June (17).

Panæolus retirugus Fr. (*rete,* a net; *ruga,* a wrinkle).
Mansfield, June (14).

Panæolus solidipes Pk. (solid-stemmed).
Mansfield, July (229). Plate XXVII.

POLYPORACEÆ Fr. *Tube-bearing Fungi.*

The Polyporaceæ are in most cases easily distinguished from members of other families by the characteristic spore-bearing surface, which is composed of more or less regular, distinct tubes, with conspicuous or inconspicuous mouths.

The substance of the fruit-body in some genera is similar to the fruit-body of the Agaricaceæ, but the spores are produced within pores on the lower surface of the cap. In some genera these pore-bearing surfaces are variously convoluted and ridged so that they resemble the gill-bearing Agarics; in other genera they are more or less torn, somewhat resembling genera of Hydnaceæ. The family is a large one, and contains many edible species, especially in the *Boletus* group, but, as in many of the Agaricaceæ, they are frequently too badly infested by larvæ to be used for food.

The plants are found abundantly in all sections of the state, growing on trees either in a parasitic or saprophytic manner, and many, especially the fleshy forms, are found on the ground, in decaying leaves or other vegetable substances.

The plants vary much in their consistency, some being fleshy, others leathery or woody. Some are annuals, others are perennials, adding new layers of growth each year. In many species of *Fomes,* the new spore-bearing surface grows

directly over the growth of the previous year, and distinct zones of annual growth are thus formed.

Some members of this family form thin plates of spore-bearing bodies over the surface of logs, or decaying wood, and resemble the other species so slightly that they are frequently not recognized by the inexperienced collector as fungi of the same family. Examples of this manner of growth may be found in *Trametes,* and such plants are spoken of as *resupinate* forms, which means that the spore-bearing surface lies upon its back, the pores always pointing outward, then downward. No classification based upon the color of the spores has yet been made, but the divisions depend principally upon the texture of the cap and the arrangement of the pores.

Dr. W. A. Murrill of the New York Botanical Gardens, Bronx Park, New York City, has done much research work in this group, especially in the genera *Polyporus, Fomes,* and *Polystictus,* and the results of his investigations may be found in the publications of the Torrey Botanical Club. Dr. Murrill very kindly identified specimens collected by Mr. C. C. Hanmer. As the nomenclature adopted in this report is that of Saccardo's "Sylloge Fungorum," the writer considered it better to follow a uniform system, but the nomenclature of Dr. Murrill is appended wherever his determination varies from the Saccardo list.

Key for the Analysis of Connecticut Genera of Polyporaceæ.

Pores free from each other though standing closely side by side, and appearing as though joined. . *Fistulina*

Pores more or less closely united. 1

1\. Pores easily separable from the cap. 2

Pores not easily separable from the cap. 4

2\. Cap covered with large scales. . . . . *Strobilomyces*

Cap not covered with large scales. 3

3\. Pores in radiating lines, tubes often adhering to cap *Boletinus*

Pores not in radiating lines. *Boletus*

4\. Pores large at first, radiating from a central stem or lateral attachment; substance of cap tough and leathery . . . . *Favolus*

Pores gill-like in concentric circles..........*Cyclomyces*
Pores glutinous..........................*Glœoporus*
Pores small and round.......................... 5
5. Pores immersed in flesh of cap, of uneven depth.... 6
Pores not immersed in flesh of cap, not of uneven depth 8
6. Pores in intricate and serpentine lines............. 7
Pores not in intricate and serpentine lines; substance of the cap corky, cap often lying upon its back.... *Trametes*
7. Lines deep and distinct; plants corky..........*Dædalea*
Lines shallow; plants somewhat gelatinous.....*Merulius*
8. Substance of fruit-body in distinct annual layers (stratose), woody..........................*Fomes*
Substance of fruit-body not in distinct annual layers. 9
9. Plants membranaceous or leathery..........*Polystictus*
Plants fleshy and tough, often becoming woody.... *Polyporus*

FISTULINA Bull.

Fistula, a pipe.

This genus is a small one with but one species reported from Connecticut. Its characteristics are very marked, so the plants are not easily confused with other genera. The tubes, or pores, are separate or distinct, but are thickly crowded on the under side of the cap, having the appearance of being united.

F. hepatica, the beefsteak mushroom, is considered edible; but its strong, acid taste makes it objectionable to many. During the past season the plants were found abundantly on chestnut stumps in the vicinity of Mansfield. They are dark red in color, and when young are very soft and juicy. From a short lateral stem the fruiting-body expands into a broad, fleshy cap which becomes very moist and sticky in wet weather.

Fistulina hepatica Fr. (resembling the liver).
Mansfield, Aug. (257).

STROBILOMYCES Berk.

στρόβιλος, a pine cone; μύκης, a fungus.

This genus resembles *Boletus,* but is easily distinguished by the large, rough scales which cover the top of the cap and thickly clothe the stem, also by stronger adhesion between the pores and the cap. The plants receive their generic name from a fancied resemblance to a pine cone. They are inconspicuous in their habitat, and are frequently overlooked by a casual observer, because of the dark colored caps with many brown tints which closely resemble the colors of fallen leaves. *S. strobilaceus* was frequently found during the past season, being by no means rare in the vicinity of Mansfield.

Strobilomyces strobilaceus (Scop.) Berk. (cone-like).
Goshen, *Underwood;* New Haven, *Clinton;* Mansfield, Aug. (311).

BOLETINUS Kalchb.

A diminutive of *Boletus.*

This genus strongly resembles *Boletus,* but the pores do not as easily separate from the substance of the cap, and they are larger, more angular, and radiate from the stem. The plants are fleshy throughout. They are found growing on the ground in open fields, in swamps and woods. Some species occur quite abundantly in Mansfield. They are especially plentiful during rainy weather, and their season of growth is long. *B. porosus* was frequently collected from under apple trees growing on the campus of the Connecticut Agricultural College. Their appearance was attractive, and they have been pronounced edible, but a strong disagreeable odor repelled any desire to prepare them for food.

Boletinus pictus Pk. (painted).
Mansfield, Aug. (307).

Boletinus porosus (Berk.) Pk. (porous).
Mansfield, Aug. (213). Plate XXVIII.

BOLETUS Dill.

βωλίτης, a name given edible fungi.

Boletus comprises the largest number of fleshy species of any of the genera of Polyporaceæ. The generic characters

PLATE XXVIII. *Boletinus porosus*. Eccentric-stemmed Boletinus. (Reduced one-half.)
Cap fleshy, chestnut-colored, viscid when moist; flesh yellow; pores large, angular.

PLATE XXIX. *Boletus Americanus.* American Boletus. (Reduced one-third.)
Cap thin, very viscid when moist, slightly tomentose on margin when young ; flesh pale yellow, pinkish-grey on exposure to air ; tubes rather large, angular ; stem slender.

are quite distinct, but the varying specific characters are so confusing that the plants are exceedingly difficult to classify. Dr. C. H. Peck has probably done more careful work on this genus than has any other American mycologist, and his illustrations and keys, published in "Reports of the New York State Botanist," are valuable. Anyone especially interested in mushrooms should have his reports, for his long experience with the fleshy and woody fungi has given him a standing foremost among mycology students. The writer considers it fortunate that he was enabled to have Dr. Peck examine the specimens collected for the Survey herbarium. No doubtful species have been reported.

The greater number of the plants in the genus grow on the ground, mostly in woods, and occur in large numbers, especially during damp weather. The caps and stems are fleshy, quickly decaying, and are frequently attacked by larvæ. They are eagerly devoured by cattle, and the writer spent an interesting hour feeding the different species to a herd of cattle. They eagerly devoured them all, even the intensely bitter *B. felleus,* at the same time positively refusing the peppery *Lactarius.*

Many of the species exhibit characteristic changes in coloring when the flesh is wounded, and these characters are of valuable assistance in their identification.

The genus is so large that it might easily furnish material for a complete report, therefore only the most striking characters are noted.

Boletus affinis Pk. (related).
Mansfield, July (260).

Boletus albellus Pk. (whitish).
South Windsor, *Hanmer.*

Boletus albus Pk. (white).
Goshen, *Underwood.*

Boletus Americanus Pk.
Goshen, *Underwood;* Mansfield July, Aug. (130, 50). Plate XXIX.

Boletus æstivalis (Paul.) Fr. (summer).
Mansfield, July (279).

PLATE XXX. *Boletus bicolor*. Two-colored Boletus. (Reduced one-third.)
Cap glabrous, dark-red; flesh yellow, not changing color where wounded; tubes bright-yellow, slowly changing to blue where wounded, mouths small, angular; stem red, generally yellow at top.

PLATE XXXI. *Boletus chromipes*. Yellow-stemmed Boletus. (Reduced one-third.)

Cap pale-red, slightly tomentose; flesh white, unchangeable; tubes more or less depressed around the stem, white or whitish, becoming brown; stem rough-spotted, chrome-yellow at the base, both without and within.

PLATE XXXII. *Boletus felleus.* Bitter Boletus. (Reduced one-half.)
Cap glabrous, variable in color, grayish-brown, reddish-brown, chestnut or pale yellow, variable in size; flesh white; taste bitter; tubes depressed around the stem, their mouths angular, white, becoming flesh-colored.

PLATE XXXIII. *Boletus piperatus.* **Peppery Boletus. (Natural size.)**
Cap glabrous, slightly viscid when **moist, yellowish, cinnamon, or reddish-brown**; flesh white or yellowish; taste acrid, **peppery; tubes large, angular**, reddish rust-color; stem slender, tawny-yellow, **bright yellow at base.**

Boletus granulatus L. (granulated).
Rainbow, South Windsor, *Hanmer;* Goshen, *Underwood.*

Boletus griseus Frost. (gray).
Mansfield, Aug. (304).

Boletus indecisus Pk. (undecided).
Mansfield, July (169).

Boletus luridus Schæff. (lurid).
Mansfield, June (37, 97).

Boletus miniato-olivaceus Frost. (reddish-olive).
Mansfield, July (137).

Boletus mutabilis Morgan. (changeable).
Mansfield, June (73).

Boletus ornatipes Pk. (ornate-stemmed).
Goshen, *Underwood;* Mansfield, July (143).

Boletus pallidus Frost. (pale).
Manchester, *Hanmer.*

Boletus parasiticus Bull. (parasitic).
Hartford, *Hanmer.*

Boletus Peckii Frost. (after C. H. Peck).
Manchester, *Hanmer;* Mansfield, Aug. (299).

Boletus piperatus Bull. (peppery).
Manchester, *Hanmer;* Mansfield, Aug. (215). Plate XXXIII.

Boletus punctipes Pk. (dotted-stemmed).
South Glastonbury, *Hanmer.*

Boletus purpureus Fr. (purple).
Mansfield, July, Aug. (123, 176).

Boletus Roxanæ Frost.
Mansfield, July (242).

Boletus Russellii Frost.
Mansfield, Aug. (277).

Boletus scaber Fr. (rough).
Mansfield, June (28).

Boletus scaber Fr. var. **alutaceus** (*aluta,* a soft leather).
Mansfield, Aug. (317).

Boletus scaber Fr. var. **areolatus** (*areola,* a little area, referring to the cuticle cracking into small squares).
Manchester, *Hanmer.*

Boletus scaber Fr. var. **mutabilis** (changeable).
Mansfield, July, Aug. (132, 263).

Boletus scaber Fr. var. **niveus** (snowy).
South Windsor, *Hanmer*.

Boletus scaber Fr. var. **olivaceus** (olive-colored).
Mansfield, Aug. (373).

Boletus scaber Fr. var. **testaceus** (brick-colored).
Mansfield, June (27).

Boletus speciosus Frost. (handsome).
Manchester, *Hanmer*.

Boletus striæpes Secr. (having a striate stem).
Mansfield, July (195).

Boletus subaureus Pk. (almost golden).
South Windsor, Manchester, *Hanmer*.

Boletus subglabripes Pk. (having the stem somewhat glabrous).
Rockville, *Hanmer;* Mansfield, Aug. (327).

Boletus subluteus L. (yellowish).
East Hartford, *Hanmer*.

Boletus subtomentosus L. (somewhat downy).
Goshen, *Underwood;* Mansfield, June, July, Aug. (70, 325).

Boletus subvelutipes Pk. (having a somewhat velvety stem.
Mansfield, July (140).

Boletus vermiculosus Pk. (wormy).
Mansfield, July (293).

Boletus vermiculosus Pk. var. **Spraguei.**
Manchester, *Hanmer*.

Boletus versipellis Fr. (changing its skin or aspect).
Mansfield, July (306).

FAVOLUS Fr.

Favus, honeycomb.

The plants of this small genus are frequently found on decaying trees. The large-mouthed, radiating pores give the under surface of the cap a peculiar honeycombed appearance. The substance of the cap is tough and leathery in texture.

Favolus canadensis Klotz.
= **Hexagona alveolaris** (D. & C.) Murrill.
Goshen, *Underwood;* New Haven, *Clinton;* Mansfield, July (119).

CYCLOMYCES Kunz & Fr.

κύκλος, a circle; μύκης, fungus.

The characters of this genus are distinct from other Polyporaceæ. The cap is fleshy, leathery, or membranaceous, and upon the lower surface are the plate-like bodies which resemble the gills of Agaricaceæ, but which are composed of minute pores. These pore-bodies are borne in concentric circles, giving the lower surface a peculiar appearance. *C. Greenii* is the only species reported, and this is not uncommon in Connecticut.

Cyclomyces Greenii Berk.
= **Cycloporus Greenii** (Berk.) Murrill.
Goshen, *Underwood;* Mansfield, July (270).

GLŒOPORUS Mont.

γλοιός, gluten; πόρος, pore.

The plants of this genus have a leathery or woody cap and a trembling, gelatinous, spore-bearing surface which is somewhat elastic. The pores are round.

Glœoporus conchoides Mont. (shell-like).
East Hartford, *Hanmer.*

TRAMETES Fr.

Trama; the generic distinction depending on the trama.

The characteristic difference between *Trametes* and other genera in this family is the unequal depth of the tubes, or pores, which are sunken into the flesh of the cap. It differs from *Dædalea* by having the pores more distinct and not arranged in serpentine lines. The plants grow on wood, and are woody or corky in texture, becoming hard with age.

Trametes cinnabarina (Jacq.) Fr. (having the color of dragon's-blood).

= **Pycnoporus cinnabarinus.**
East Hartford, *Hanmer.*

Trametes odora Fr. (scented).
East Hartford, *Hanmer.*

Trametes sepium Berk. (σήπω, to become rotten).
Poquonock, *Hanmer.*

DÆDALEA Pers.

δαιδάλεος, curiously wrought.

The plants belonging to this genus are found growing on wood, many being especially abundant upon decaying stumps. The peculiar, convoluted appearance of the under surface of the cap is due to the serpentine formation of the pore structure. These pores are rather deep, and the lines somewhat distant. The pore substance is not unlike the cap substance, both being corky in texture. *D. quercina* is perhaps the most common species and occurs abundantly on decaying stumps, especially oak. The distinct character of the pores always identifies it at a glance. The substance of the cap is very closely united with that of the fungus tissue within the wood, and the plant is removed from the host with difficulty. Some few species are attached to the feeding substance by the back of the cap (resupinate), that is, the back of the cap lies flat against the log, the pore surface pointing outward.

Dædalea confragosa Pers. (rough, rugged).
East Hartford, *Hanmer;* Goshen, *Underwood;* New Haven, *Clinton.* Plate XXXIV, at the right.
Mansfield, Feb. (361).

Dædalea quercina (L.) Pers. (pertaining to the oak).
Goshen, *Underwood;* New Haven, *Clinton;* Mansfield, Mar. (363). Plate XXXIV, at the left.

Dædalea unicolor (Bull.) Fr. (one-colored).
Goshen, *Underwood;* New Haven, *Clinton;* Mansfield, Mar. (360).

MERULIUS Fr.

Merula, a blackbird; probably from the color of the fungus.

Merulius is a small genus whose species are somewhat

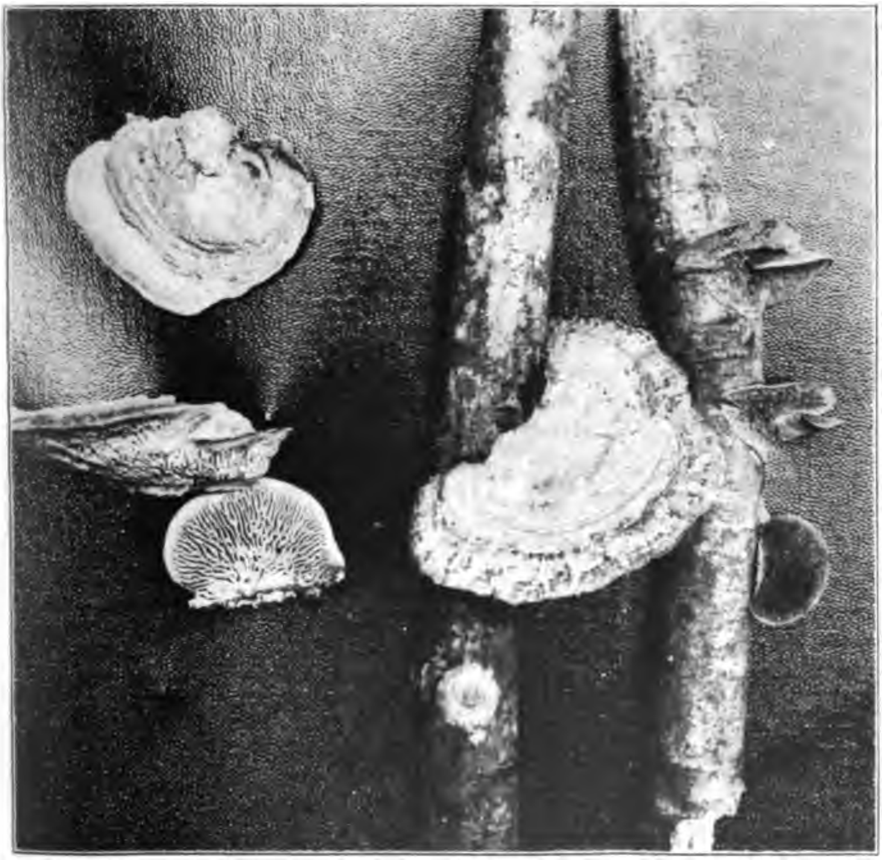


PLATE XXXIV. At the left, *Dædalea quercina.* Oak Dædalea.
At the right, *Dædalea confragosa.* Rough Dædalea.

PLATE XXXV. The upper specimen, *Fomes applanatus.* Flattened Fomes. (Reduced one-half.)
The lower specimens, *Fomes fomentarius.* Smoky Fomes.
Colors of older growth dark gray, tinged with brown, recent growth light gray ; substance of cap woody.

gelatinous in substance. The pore surface consists of serpentine lines, but these lines are much more shallow than in *Dædalea,* appearing as small pits. The plants are usually attached to the substratum by the back of the cap (resupinate).

Merulius lachrymans Fr. (weeping; referring to the watery drops on the pileus).
East Hartford, *Hanmer;* New Haven, *Clinton.*

Merulius tremellosus Sch. (resembling *Tremella*).
New Haven, *Clinton.*

FOMES Fr.

Fomes, tinder.

The plants of this genus are separated from other genera of the Polyporaceæ by the hard and woody texture of the cap, even in the young plants. This cap is covered by a hard, rigid cuticle which is not zoned, but the plants are perennial growers, adding a new layer of tissue over that of the preceding year, making them distinctly *stratose.* In other words, the substance of the cap is composed of layers of mycelium and spore-bearing tissue. These layers may be seen if a cross section be made. As the new mycelial tissue spreads over the old, the latter dies, so that only the new growth is the living substance of the plant.

The species of *Fomes* are classed by the older writers in the genus *Polyporus.*

Fomes annosus (Fr.) Cooke. (aged).
East Hartford, *Hanmer.*

Fomes applanatus (Pers.) Fr. (*plano,* to level).
East Hartford, *Hanmer;* Mansfield, April. Plate XXXV; the upper specimen.

Fomes fomentarius (L.) Fr. (smoky).
= **Elfvingia fomentaria** (L.) Murrill.
Mansfield, March (350). Plate XXXV; the lower specimens.

Fomes igniarius (L.) Fr. (fiery).
= **Pyropolyporus igniarius** (L.) Murrill.
Goshen, *Underwood;* Mansfield, May (351).

Fomes lucidus (Leys.) Fr. (shining).
= **Ganoderma**, various species, Murrill.
East Hartford *Hanmer;* Mansfield, June; New Haven, *Clinton.*

Fomes roseus (A. & S.) Fr. (rose-colored).
East Hartford, *Hanmer;* Goshen, *Underwood.*

Fomes salicinus (Pers.) Fr. (pertaining to the willow).
= **Pyropolyporus conchatus** (Pers.) Murrill.
Goshen, *Underwood.*

POLYSTICTUS Fr.

πολύς, many; στικτός, punctate.

In this genus, the cap is leathery, membranaceous, rather spongy, and with a thin cuticle. The tubes run to an equal depth in the substance of the cap; this fact separates the genus from *Trametes,* which it strongly resembles. The substance of the cap is never fleshy or woody, and not stratose, thus making it unlike *Polyporus* or *Fomes.*

The pileus is usually zoned, frequently velvety, but may be rough with stiff hairs. The stem may be central, lateral, or absent. The plants are classed by the older writers with *Polyporus.*

Polystictus cinnamomeus Jacq. (cinnamon-colored).
= **Coltricia cinnamomea** (Jacq.) Murrill.
East Hartford, *Hanmer;* Goshen, *Underwood.*

Polystictus cinnabarinus (Jacq.) Fr. (having color of dragon's-blood).
Goshen, *Underwood;* New Haven, *Clinton;* Mansfield, May (352).

Polystictus conchifer Schw. (shell-bearing).
= **Poronidulus conchifer** (Schw.) Murrill.
East Hartford, *Hanmer;* New Haven, *Clinton;* Mansfield, May (356).

Polystictus hirsutus Fr. (hairy).
Goshen, *Underwood;* New Haven, *Clinton;* Mansfield, May (357).

Polystictus perennis (Linn.) Fr. (perennial).
= **Coltricia perennis** (Linn.) Murrill.
East Hartford, *Hanmer.*

PLATE XXXVI. *Polystictus versicolor.* Variegated Polystictus.
(Natural size.)
Cap variegated with differently colored zones, leathery, thin, velvety ; pores minute, round.

...nus. Birch Polyporus.
(... one-half.)
... zoneless, smooth ; pores minute.

Polystictus pergamenus Fr. (*pergamena,* parchment).
East Hartford, *Hanmer;* Mansfield, June (359).
Polystictus velutinus Fr. (velvety).
Goshen, *Underwood.*
Polystictus versicolor (Linn.) Fr. (changeable in color).
East Hartford, *Hanmer;* Goshen, *Underwood;* Mansfield, June (355); New Haven, *Clinton.* Plate XXXVI.
Polystictus zonatus Fr. (zoned).
Mansfield, Mar. (358).

POLYPORUS Fr.

πολύς, many; πόρος, pore.

These plants have a more or less fleshy texture when young, becoming harder with age. The genus is distinguished from *Fomes* by its lack of stratose layers of tubes within the cap. The pileus is not zoned, and it has a thicker flesh than the species of *Polystictus.*

The members of this genus are numerous, and are varied in their habit of growth. In some species the stem is central, but more often it is attached at one side of the cap (lateral), and sometimes it is wanting, the plants becoming sessile.

The species are commonly found growing on wood, in nearly all sections of the state, and are decidedly varied in their individual colors, shapes, and general habits of growth. *P. betulina* is so abundant upon grey birch trees that it is familiar to the most inexperienced collector.

Polyporus adustus (Willd.) Fr. (scorched).
= **Bjerkanderma adusta** Murrill.
East Hartford, *Hanmer;* Mansfield, May (353).
Polyporus Berkeleyi Fr.
= **Grifola Berkeleyi** (Fr.) Murrill.
East Hartford, *Hanmer.*
Polyporus betulinus Fr. (pertaining to the birch).
= **Piptoporus suberosus** (L.) Murrill.
East Hartford, *Hanmer;* New Haven, *Clinton;* Mansfield, Mar. (354). Plate XXXVII.

Polyporus brumalis (Pers.) Fr. (belonging to winter).
= **Polyporus Polyporus** (Retz.) Murrill.
East Hartford, *Hanmer;* Mansfield, May (19).

Polyporus cæsius (Schrad.) Fr. (bluish-gray).
Goshen, *Underwood.*

Polyporus chioneus Fr. (snow-white).
East Hartford, *Hanmer.*

Polyporus elegans (Bull.) Fr. (elegant).
East Hartford, *Hanmer;* Goshen, *Underwood;* Mansfield, July (36).

Polyporus fragrans Peck. (fragrant).
East Hartford, *Hanmer.*

Polyporus frondosus Fr. (leafy).
= **Grifola frondosa** (Dicks.) (S. F. Gray) Murrill.
Mansfield, Aug. (370).

Polyporus galactinus Berk. (milky-white).
East Hartford, *Hanmer.*

Polyporus gilvus Schw. (pale yellow).
= **Hapalopilus gilvus** (Schw.) Murrill.
East Hartford, *Hanmer.*

Polyporus hispidus (Bull.) Fr. (hispid).
= **Inonotus hirsutus** (Scop.) Murrill.
East Hartford, *Hanmer;* New Haven, *Clinton;* Mansfield, Apr. (368).

Polyporus leucomelas (Pers.) Fr. (λευκός, white; μελάς, black; allusion to change of color).
New Haven, *Clinton;* Mansfield, Aug. (337).

Polyporus rutilans (Pers.) Fr. (reddish).
= **Hapalopilus rutilans** (Pers.) Murrill.
East Hartford, *Hanmer.*

Polyporus Schweinitzii Fr.
= **Romellia sistotremoides** (A. & S.) Murrill.
East Hartford, *Hanmer;* Goshen, *Underwood.*

Polyporus semipileatus Peck. (half-capped).
East Hartford, *Hanmer.*

Polyporus sulphureus (Bull.) Fr. (sulphur-yellow).
= **Lætiporus speciosus** (Batarr.) Murrill.
Goshen, *Underwood;* Mansfield, July (369).

Polyporus squamosus (Huds.) Fr. (scaly).
East Hartford, *Hanmer;* Tolland, July (368).

HYDNACEÆ Fr. *Spine-bearing Fungi.*

The members of this family are easily recognized because of the distinct, spiny, spore-bearing surface of the cap; yet their varying generic and specific characters are puzzling to the amateur collector. The plants vary widely in their habits of growth; some are found growing in a shelving position from trunks of trees, thus resembling certain Polyporaceæ; others grow on the ground, closely resembling Agaricaceæ; still others attach themselves very closely to the bark of trees, in the peculiar way described in the family characteristic of Polyporaceæ, as resupinate. In these resupinate forms, only the spiny, spore-bearing surface is visible; the spines always growing directly towards the ground, which distinguishes the group from the Clavariaceæ in which the spiny projections are vertical.

Most of the species have the typical mushroom form; that is, they have a more or less expanded cap, with a central, well defined stem; but in some species the stem is wanting, and the caps are attached directly to the substratum (sessile).

A few species are edible, but as a rule the plants are tough and leathery in consistency.

There are several distinct genera in this family, but only two are reported.

Key for the analysis of Connecticut Genera of Hydnaceæ.

Spines springing from folds or ridges which may branch irregularly; cap thin, spread out over the surface of the wood (resupinate)................................*Irpex*

Spines springing from an even surface, distinct at base; cap fleshy; stem central, attached at one side of the cap, or absent; plants often resupinate...............*Hydnum*

IRPEX Fr.

Irpex, a harrow.

The plants of this genus are all resupinate, that is, they spread themselves over logs, the teeth extending outward and downward. The spines are less sharply pointed and awl-shaped than in *Hydnum,* and are more or less connected at the

base into ridges, which somewhat resemble the convolutions of the fruiting-surface of *Dædalea*. The substance of the fruit-body is leathery.

Irpex cinnamomeus Fr. (cinnamon-colored).
Goshen, *Underwood.*

Irpex lacteus Fr. (milk-white).
East Hartford, *Hanmer;* Goshen, *Underwood.*

Irpex mollis B. & C. (soft).
Mansfield, May (347).

HYDNUM Linn.

ὕδνον, a kind of fungus.

In *Hydnum,* the fruiting-surface consists of distinct spines which are often somewhat branched at the tips. They vary greatly in form, and the species are difficult of determination because of a lack of technical American literature upon this group. They grow on the ground or upon wood, usually in woodlands. They are especially frequent as fall approaches, and many of the earth-growing species are overlooked by the collector because of their resemblance in color to fallen leaves. Several of the wood-growing plants are beautifully tufted into coral forms, thus resembling Clavariaceæ, but their spines always point downward, never upward as do the Clavarias.

Many species are listed as edible.

Hydnum adustum Schw. (scorched).
East Hartford, *Hanmer;* Goshen, *Underwood;* Mansfield, July, Aug. (165, 324).

Hydnum albidum Pk. (white).
Mansfield, Aug. (309).

Hydnum albo-nigrum Pk. (*albus,* white; *niger,* black; allusion to change of color).
South Windsor, *Hanmer;* Mansfield, July (219).

Hydnum aurantiacum A. & S. (orange-colored).
Ledyard, *Hanmer;* Mansfield, Aug. (338).

Hydnum caput-ursi Fr. (bear's head).
South Windsor, *Hanmer.* Edible (Curtis).

Hydnum compactum Pers. (compact).
Goshen, *Underwood.*

PLATE XXXVIII. *Hydnum septentrionale.* Northern Hydnum.
(Reduced one-half.)
Caps white, fleshy-fibrous, imbricated; spines very crowded, slender, equal.

Hydnum coralloides (coral-like).
East Hartford, *Hanmer.* Edible (Curtis).

Hydnum ferrugineum (Scop.) Fr. (rust-colored).
Rockville, *Hanmer.* Edible (McI.).

Hydnum graveolens Del. (strong-smelling).
Ledyard, *Hanmer.*

Hydnum imbricatum L. (imbricated).
North Glastonbury, *Hanmer;* Mansfield, Aug. (45). Edible (Curtis).

Hydnum ochraceum Pers. (ochre-yellow).
Poquonock, *Hanmer.*

Hydnum repandum L. (bent backward).
East Hartford, *Hanmer;* Mansfield, July (239). Edible (Curtis).

Hydnum rufescens Pers. (reddish).
Mansfield, July (160). Edible (Curtis).

Hydnum scabrosum Fr. (rough).
Mansfield, Aug. (231).

Hydnum scrobiculatum Fr. (*scrobiculus,* a little trench; from the slightly pitted cap).
Rainbow, *Hanmer.*

Hydnum septentrionale Fr. (northern).
South Windsor, *Hanmer;* Mansfield, Aug. Plate XXXVIII.

Hydnum squamosum Schæff. (scaly).
Mansfield, July (247).

Hydnum umbilicatum Pk. (umbilicate).
Rainbow, *Hanmer.*

Hydnum vellereum Pk. (fleecy).
Mansfield, Aug. (310).

Hydnum zonatum Batsch. (zoned).
Mansfield, June (100).

THELEPHORACEÆ Pers.

This family contains plants similar in appearance to other families described, but they are generally distinguished by a perfectly plane fruiting-surface. In some few genera, however, this surface may be radiately wrinkled, or velvety from minutely projecting cystidia. The reproductive spores are borne as in other families.

Key for the analysis of Connecticut Genera of Thelephoraceæ.

Spores colored, substance of plant leathery, dry and fibrous, fruiting-surface wrinkled......... *Thelephora*
Spores colorless................................. 1
1. Fruiting-surface minutely velvety, with rigid, smooth, colored, projecting cystidia.... *Hymenochæte*
Fruiting-surface smooth......................... 2
2. Plants funnel-shaped or cup-shaped.............. 3
Plants not funnel-shaped or cup-shaped........... 4
3. Plants large, funnel-shaped, substance fleshy or membranaceous .... *Craterellus*
Plants small, cup-shaped, substance thin....... *Cyphella*
4. Surface of cap velvety, fruiting-surface not cracked in drying.............................. *Stereum*
Plants smooth throughout, waxy, polished, entirely resupinate, fruiting-surface cracked when dry.. *Corticium*

THELEPHORA Ehrh.

θηλή, a teat; φορέω, to bear.

In this genus, the substance of the fruit-body is dry and fibrous, somewhat leathery in texture, and lacks a distinct cuticle. The fruiting-surface is slightly wrinkled and bears colored, minutely warted spores. Many species are soft and elastic but never gelatinous.

Thelephora anthocephala (ἄνθος, flower; κεφαλή, head).
Goshen, *Underwood.*

Thelephora intybacea Pers. (resembling chicory).
Hartford, *Hanmer.*

Thelephora pallida Pers. (pale).
Waterbury, *Hanmer.*

Thelephora palmata (Scop.) Fr. (palmate).
Glastonbury, *Hanmer.*

Thelephora radiata Fr. (radiated).
East Hartford, *Hanmer.*

Thelephora terrestris Ehrh. (pertaining to the earth).
East Hartford, South Windsor, *Hanmer.*

PLATE XXXIX. *Craterellus cornucopioides.* Cornucopia Craterellus. (Natural size.)
Cap dark gray or brown, becoming black with age, funnel-shaped, mouth wavy, split or in folds ; flesh thin, brittle or tough ; fruiting surface slightly uneven.

HYMENOCHÆTE Lev.

ὑμήν, membrane; χαίτη, a bristle.

In Hymenochæte, the cap may be attached to the substratum by a central stem, at one side, or upon its back (resupinate). The distinguishing character of the genus is the velvety or bristly appearance of the fruiting-surface, due to smooth, projecting, thick-walled cells (cystidia or setæ).

Only one species was collected during the past season, but this was found abundantly upon decaying chestnut stumps.

Hymenochæte rubiginosa (Schr.) Lev. (rusty).
Mansfield, May (344).

CRATERELLUS Fr.

Crater, a bowl.

Craterellus very closely resembles *Cantharellus* of the Agaricaceæ family, but is distinguished by a smooth fruiting-surface, while in *Cantharellus* the fruiting-surface is composed of thick blunt gills. The plants are very common in the autumn. They are funnel-shaped, and of a fleshy, waxy, or membranaceous consistency.

Craterellus cantharellus (Schw.) Fr. (a small vase).
New Haven, *Clinton.*

Craterellus conucopioides (L.) Pers. (resembling a horn of plenty).
Mansfield, Aug. (245). Plate XXXIX.

CYPHELLA Fr.

κύφελλον, an ear-like depression.

The plants of this genus are small, cup-like, and resemble *Peziza* of the Discomycetes. Some species are similar to *Corticium,* but are distinguished by being attached to the substratum at a central point, and not by the whole sterile surface. Then, too, the fruiting-surface has a tendency to turn downward away from the light, while in *Corticium* it turns towards the light.

Cyphella muscigena (Pers.) Fr. (growing on moss).
South Windsor, *Hanmer.*

STEREUM Pers.

στερεός, solid, hard.

Stereum is distinguished by the smooth, plane, fruiting-surface and the velvety or hairy upper surface of the cap.

In some species the plants have a well-defined central stem, in others the side of the cap is attached to the substratum, while in still others the cap lies upon its back (resupinate).

Stereum complicatum Fr. (complicated).
Mansfield, July (364).

Stereum fasciatum Schw. (bundled).
East Hartford, *Hanmer.*

Stereum gausapatum Fr. (*gausapa,* a shaggy woolen cloth).
East Hartford, *Hanmer.*

Stereum hirsutum (W.) Fr. (hairy).
New Haven, *Clinton.*

Stereum sericeum Schw. (silky).
Bolton, *Hanmer;* Mansfield, Aug. (365).

CORTICIUM Fr.

Cortex, bark or rind.

These plants are always resupinate, the caps lying upon their backs, closely attached to the surface of the bark of logs. The edges are frequently free and curl outward. The fruiting-surface is perfectly smooth and often polished. When dry, the fruiting-surface is often cracked, due to the contraction of the mycelial tissue of the cap. The genus, in many ways, resembles *Stereum,* but the latter genus is often shelving, the surface of the cap velvety, and the fruiting-surface uncracked when dry.

Corticium incarnatum (Pers.) Fr. (flesh-colored).
Goshen, *Underwood.*

Corticium salicinum Fr. (pertaining to the willow).
Goshen, *Underwood;* New Haven, Clinton.

Corticium vagum B. & C. (uncertain) var. **Solani.**
New Haven, *Clinton.*

CLAVARIACEÆ. *Coral Fungi.*

This is a family very unlike most families of mushrooms. There is no distinct cap; but, true to their name, the plants resemble coral formations. The substance of the plants is similar throughout, and the spores are borne over their entire upper surface. They are upright growers, and are frequently variously branched, but may be simple and club-shaped. They have striking characters not easily mistaken. The majority of the species are edible, though some are tough and leathery.

The plants are very common and occur abundantly throughout the season. They grow mostly in soil or in decaying leaves, but some few species grow on decaying wood. They are distinguished from the coral forms of Hydnaceæ by their upright habit of growth, the tips of the branches pointing away from the earth, while in Hydnaceæ the spines point downward. Some of the branched forms resemble certain species of Thelephoraceæ, but in Thelephoraceæ the tips of the branches are more or less flattened or blunt and bear no fruiting-bodies, while in Clavariaceæ the tips of the branches are acute and fertile.

The fruiting cells are not unlike those of Agaricaceæ and other Hymeniales. Over the entire surface of the fruit-body, the club-shaped basidia may be found by microscopical examination, and from these cells sterigmata arise, each bearing at its tip the basidiospore, or reproductive body.

Saccardo lists nine genera in this family, but only two are reported from Connecticut.

Key for the analysis of Connecticut Genera of Clavariaceæ.

Plants fleshy, simple or branched.................. *Clavaria*
Plants leathery, branched, tomentose......... *Lachnocladium*

CLAVARIA Vaill.

Clava, a club.

The plants in this genus are more or less fleshy in consistency. They may be variously branched, but in many species they are simple and club-shaped. The branches are typically round, and are acute at the tips. The species are diffi-

cult to determine. The plants vary in their colorings; some are white, others red, yellow, or violet, and these colors, with the color of the spores, form a basis for the determination of the species. The spores are white, ochre-colored, or cinnamon.

Clavaria aurea Schæff. (golden).
Mansfield, July (61).

Clavaria cinerea Bull. (ashy).
East Hartford, *Hanmer;* Mansfield, Aug. (256).

Clavaria flava Schæff. (yellow).
Mansfield, June, Aug. (30, 250). Plate XL.

Clavaria fusiformis Sow. (spindle-shaped).
Waterford, *Hanmer*; Goshen, *Underwood.*

Clavaria Schäfferi Sacc.
Mansfield, July, *Hanmer.*

Clavaria pyxidata Pers. (box-like).
South Glastonbury, Bolton, *Hanmer;* Mansfield, July (186).

Clavaria pulchra Peck. (beautiful).
East Hartford, *Hanmer.*

Clavaria rugosa Bull. (wrinkled).
Rainbow, *Hanmer.*

Clavaria vermicularis (Scop.) Fr. (wormy).
Rainbow, *Hanmer.*

LACHNOCLADIUM Lev.

λάχνος, fleece; κλάδος branch.

These plants are distinguished from *Clavaria* by the somewhat leathery tissue of the fruit-body. This tissue is sometimes brittle and cartilaginous. The plants are more or less branched, and are found growing on the ground or on wood. They are frequently covered with a close, soft pubescence.

Lachnocladium Micheneri B. & C.
East Hartford, *Hanmer.*

Lachnocladium odoratum Atk. (odorous).
Mansfield.

A new species, soon to be described by Professor Atkinson.

Plate XL. *Clavaria flava.* Yellow Clavaria. (Reduced one-third, often larger.)
Branches very numerous, fragile, yellow, tips toothed ; stem thick, fleshy, white, much branched ; flesh white ; spores white.

HYPOCHNACEÆ.

The plants of this family are mold-like or spider-web-like in substance, and lack the close, membranaceous character of other families. The tufts of basidia are placed closely side by side over the surface of the mycelial tissue.

No plants belonging to this family have been reported.

General Index.

Index to Species.

State of Connecticut

State Geological and Natural History Survey

BULLETIN No. 4

THE CLAYS AND CLAY INDUSTRIES OF CONNECTICUT

By

GERALD FRANCIS LOUGHLIN, S.B.

State of Connecticut

PUBLIC DOCUMENT No. 47

State Geological and Natural History Survey

COMMISSIONERS

ABIRAM CHAMBERLAIN, Governor of Connecticut *(Chairman)*
ARTHUR TWINING HADLEY, President of Yale University
BRADFORD PAUL RAYMOND, President of Wesleyan University
FLAVEL SWEETEN LUTHER, President of Trinity College *(Secretary)*
RUFUS WHITTAKER STIMSON, President of Connecticut Agricultural College

SUPERINTENDENT
WILLIAM NORTH RICE

BULLETIN No. 4

HARTFORD PRESS
The Case, Lockwood & Brainard Company
1905

THE

CLAYS AND CLAY INDUSTRIES OF CONNECTICUT

By

GERALD FRANCIS LOUGHLIN, S.B.

HARTFORD PRESS:

THE CASE, LOCKWOOD & BRAINARD COMPANY

1905

Table of Contents.

Part I.

THE CLAYS OF CONNECTICUT.

Part II.

THE CLAY INDUSTRIES OF CONNECTICUT.

Illustrations.

Preface.

The field work on which this report is based was carried on during the summer vacation of 1903 under the direction of Professor Herbert E. Gregory of the United States Geological Survey, and the laboratory work was done at brief intervals during the following winter. The appropriation for the laboratory work was so limited that no thorough tests requiring special apparatus could be made. The statements made in the text, therefore, are based on what simple tests could be made and on calculations from analyses, and are only approximate.

No research work was attempted in the laboratory. The chapters devoted to the composition and properties of clay are simply reviews of previous work, and are intended to give the reader a general knowledge of the subject.

The limited time at the writer's disposal made it impossible to do detailed work, so the report is essentially preliminary in its nature, and could be well followed by one devoted especially to the making of practical tests.

Thanks are due to Professor Herbert E. Gregory and Dr. H. H. Robinson of New Haven, and Professors W. O. Crosby and C. H. Warren of Boston, who gave valuable advice during the work; to Professor W. H. Hobbs of Madison, Wis., who kindly furnished the geological information regarding the kaolin deposits of the western highlands; to the city engineering department of Hartford, and to Mr. C. L. Grant of Hartford, who furnished records of sewer profiles and borings; to the manufacturers who furnished the illustrations of their machines; and to all the clay-working firms in the state who contributed the information asked of them.

CHAPTER I.

The Geographical Distribution of the Connecticut Clays.

The clays of Connecticut which are at present being worked are limited to the central, lowland portion of the state, and to West Cornwall in Litchfield County. The clays of central Connecticut occur in level stretches of land between ridges of higher ground. They are often several miles in length and breadth; their height above sea level varies from the neighborhood of 90 feet at the northern boundary of the state to zero at North Haven and Quinnipiac; they are always traversed by rivers or streams, the depth of which below the surface is a very important factor in the drainage of clay pits.

DISTRIBUTION OF BRICK CLAYS.

The distribution of the clays in central Connecticut is shown in the map, Plate I.

Northern Area. — By far the largest clay area in the state is that including the brick yards in and north of Hartford. Examination of stream cuttings, well borings, and sewer profiles shows that the clay is continuous along the valley of the Connecticut River from Wethersfield north to Windsor Locks, probably passes east of the ridge at Enfield, and is continuous with the clay deposit that extends from Thompsonville northward to Springfield and Holyoke in Massachusetts. The width of the deposit varies. At Hartford it lies principally west of the river, and is from four to five miles in width. It then extends northeastward, and, at South Windsor, lies mostly east of the river. The width of workable clay in this neighborhood is from two to five miles. The workable part of the deposit narrows towards the north, and disappears just south of King's Island. From Thompsonville to King's Island the Connecticut River flows over bed rock.

The true extent of the clay east of the river is uncertain.

Detailed study of the region shows that clay, generally in workable deposits, extends along the Broad Brook Valley as far as Broad Brook Village; but the actual extent eastward and northward is obscured by a covering of sand often of great thickness. The nature of the topography, however, strongly suggests that clay underlies at least the western part of this large sandy area, and unites the beds south of King's Island with those at Thompsonville.

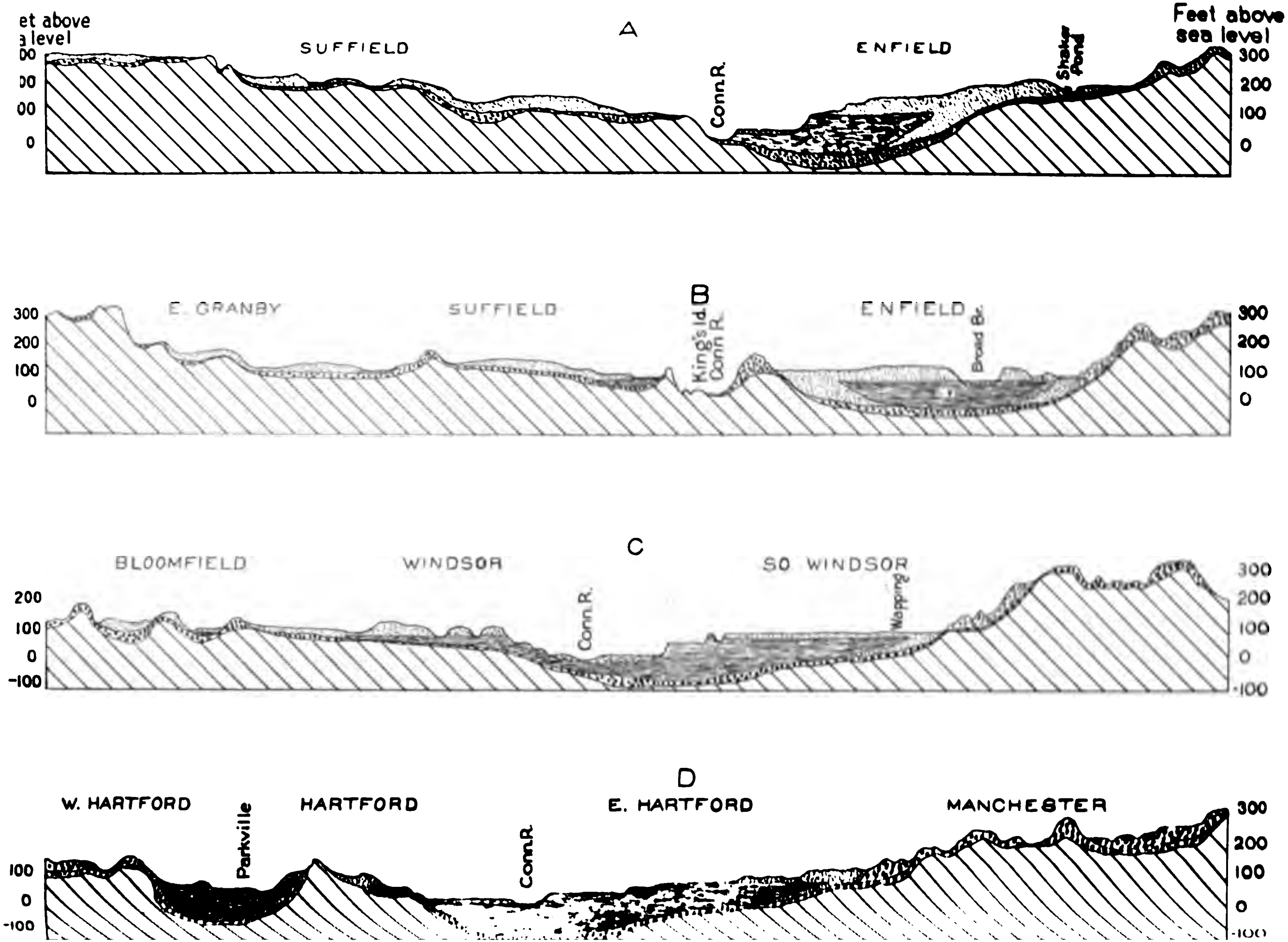
The depth of this large clay formation is also variable, owing to the irregularity of the bed-rock surface. The sections across the deposit shown in Plate II will give the best idea of its depth at different points, and its general extent underground. The data were taken from records of well borings and sewer profiles.

The following are the records of depths obtained: —

Locality.	Depth in feet.
East Longmeadow, stream cuts (blue clay)	20+
Thompsonville, Alden's brick yard (blue clay)	20+
Warehouse Point	0
Windsor Locks (blue clay)	60
Ketch Brook, at road one mile west of R. R. (blue clay)	0 to 5
South Windsor, yard of E. W. Hill Brick Co. (blue clay)	35+
" " Meade & Mullaly's brick yard (blue clay)	30+
Windsor, Elijah Mills & Son's brick yard (blue clay)	30+
" Curtis's brick yard (red and blue clay resting on shale)	18
Bloomfield, (clay and quicksand)	28 to 47
Hartford, Main Street (yellow and red clay)	5 to 12
" Allyn House, Asylum Street (blue clay)	28
" Park Street, at brewery (blue clay)	43
Parkville, Dennis's brick yard (blue clay)	95
Elmwood, yard of Hartford Brick Co. (blue over red clay)	85
" yard of Park Brick Co. (light brownish clay)	95
" Goodwin Bros.' Pottery Works (blue and red clay)	40?
" at railroad station (red clay)	56
" half mile west of R. R. station (clay pinches out under 56 feet of sand).	

(The + sign after figures indicates that the clay extends further for an unknown depth.)

In all these places, save at Parkville, the clay is overlain by a varying thickness of reddish or yellow sand. The clay is usually underlain by hardpan and bed rock, but along the


A
et above
a level
Feet above
sea level
SUFFIELD
Conn.R.
ENFIELD
Shaker Pond
B
E. GRANBY
SUFFIELD
King's Id.
Conn R.
ENFIELD
Broad Br.
C
BLOOMFIELD
WINDSOR
Conn.R.
SO. WINDSOR
Wapping
D
W. HARTFORD
Parkville
HARTFORD
Conn.R.
E. HARTFORD
MANCHESTER

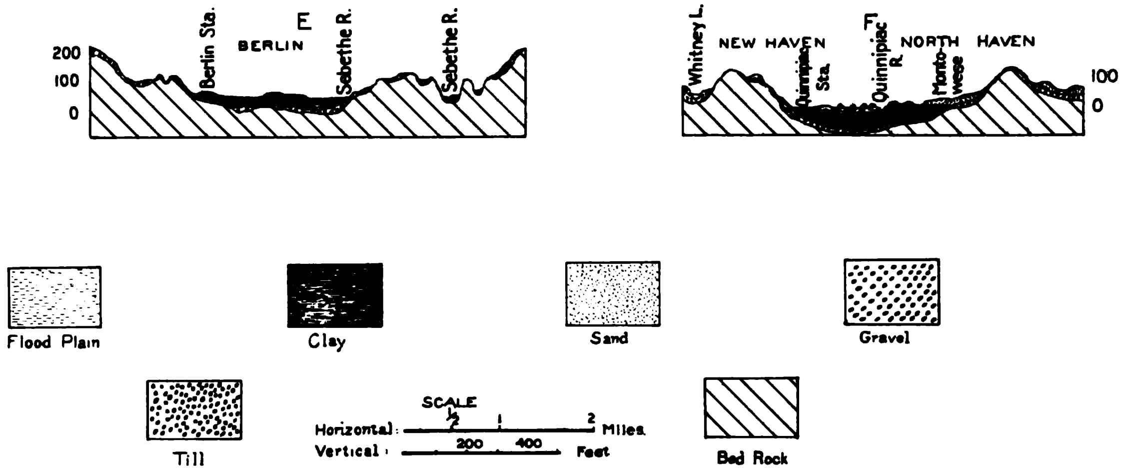


PLATE II. – SECTIONS ACROSS THE CLAY AREAS OF CONNECTICUT.

A. Connecticut valley at northern boundary of state.
B. Connecticut valley at King's Island.
C. Connecticut valley at Windsor.
D. Connecticut valley at Parkville and southern Hartford.
E. Berlin area, along E-W line through Berlin railroad station.
F. Quinnipiac area, along E-W line through Quinnipiac station and Montowese.

margins of the deposit, as at Ketch Brook, it shades downward into sand. The character of the clay is very uniform throughout. It is composed of thin, blue, and sometimes red and blue, layers of very plastic clay, which alternate with layers of very fine quicksand. These layers are generally horizontal, but are sometimes gently undulating.

Clayton Area. — At Clayton, two miles west of Newington Centre, there is a small deposit of reddish clay. Its relation to the other clay deposits to the north and south is not definitely known. The general topography would lead one at first to regard it as the southern extremity of the Connecticut River beds; but frequent low outcrops of red shale exposed along the railroad between Clayton and Newington stations do not favor this view. The character of the clay, furthermore, is somewhat different. It is of a uniform brownish red color, similar to the deposits to the south. The layers of clay and quicksand are often ten inches to a foot in thickness, and, as shown by the sections in the clay banks, lie in long, pronounced undulations, while the surface of the clay is at least 20 feet above that of the deposit to the north, and 40 feet above the surface of the Berlin clay to the south. The clay has been mined to a depth of 15 to 20 feet, but the full depth is unknown. Its actual extent is also indefinite, as it is overlain by a thick covering of coarse sand; but the proximity of trap and sandstone ridges shows that the extent is very limited, while the workable clay is limited to the hillside where the two brick yards of Clayton are situated.

Berlin Area. — The brownish red clay at Berlin is the western extremity of a narrow deposit (of like color) that extends, with one or two probable breaks, along the valley of the Sebethe River to Cromwell and Middletown along the Connecticut River. The surface of the deposit is marked by a nearly level plain, the elevation of which diminishes from 60 feet above sea level at Berlin to less than 40 feet at Cromwell and Middletown. Although the deposit as a whole is horizontal, the layers of clay are often so badly contorted and squeezed together that nearly all evidence of stratification is lost. The clay, as in the northern area, is characterized by alternating layers of plastic, or "strong" clay, and quicksand, but in some

places is of a uniform and comparatively sandy texture throughout. These more sandy places are generally near the boundaries of the area. The thickness of the clay varies, as shown in the section, Plate II, E.

The depths of clay obtained are as follows: —

Locality.	Depth in feet.
Berlin, yard of Berlin Brick Co. (brown clay)	27+
" east of Merwyn's brick yard (brown clay)	60?
Beckley P. O., yard of American Brick Co. (brown clay)	85+
Newfield, Johnson's brick yard (brown clay)	30+

Quinnipiac Area. — The clay deposit of the Quinnipiac Valley extends from North Haven station southward into New Haven. Its width increases from North Haven southward to a maximum of about two miles, where it stretches from the vicinity of Scheutzen Park, New Haven, across the broad, marshy meadow to Montowese. Owing to the marshy condition of the area, which is occasionally covered by flood tides, only the margins of the area can be worked. (See Plate III.) The character of the clay is identical with that of the Berlin area, brownish red in color, generally banded and sometimes contorted, and often sandy near the margins. The clay is usually overlain by three to five feet of peat. The depth of the clay could be ascertained only along the margins of the area. The following records were obtained: —

Locality.	Depth in feet.
North Haven, I. L. Stiles & Sons' brick yard (overlain by more than three feet of yellow sand)	15 to 30
Quinnipiac, Shares's brick yard	6 to 20
" Davis's brick yard,	20+
" Brockett's brick yard	25+

South of Davis's yard, the clay surface drops suddenly, and is overlain by over 18 feet of black mud.

Milldale Area. — The only remaining area where clay is being worked at present is at Milldale. This deposit is in a flat, enclosed valley, and is by far the smallest of all the deposits mentioned. The clay is of the same color as that in the Berlin and Quinnipiac areas, and is of sandy character

PLATE III. — THE QUINNIPIAC CLAY AREA, AS SEEN FROM EAST ROCK, NEW HAVEN.

The brick yards are located along the edge of the flat in the central part of picture. The ponds in central part mark abandoned clay pits

where exposed; but only one exposure was seen, and that was near the margin, where the clay is naturally more sandy than in the central portion. The depth of the clay at this exposure is 15 feet. No other data were available.

Other Areas. — There are several other areas, of limited extent, where clay may be found; but, as they are all more or less similar to those described above, and are relatively unimportant, and are not being worked at present, further mention of them is unnecessary. Clay was formerly worked at Brooklyn and Wauregan in the eastern part of the state, where limited clay areas occur.

DISTRIBUTION OF OTHER CLAYS.

West Cornwall Kaolin Deposit. — At West Cornwall, in Litchfield County, there is a bed of kaolin, or porcelain clay, which, owing to its unique mode of origin, to be described later, has a larger surface area than any other known kaolin deposit in the United States. It has a length of at least 1,000 feet, a width of over 400 feet, and a depth of over 35 feet.[1] The kaolin is white in color, and of a sandy or granular texture.

Other Deposits. — There is another deposit of kaolin in Cornwall Hollow, which occurs as a vein in the rock, and has been exploited. C. U. Shepard[2] in 1837 stated that there was a bed of porcelain clay covering several acres in New Milford. He also mentioned porcelain clay as being found in Sherman, Kent, and Granby.

There is a deposit of fire-clay, similar in composition to kaolin, about two miles south-southwest of Boardman's Bridge, Litchfield County. This deposit was once worked on a small scale. There may be one or two other deposits of a similar clay in Fairfield County, but they are unimportant, and have not been visited.

1 These figures were taken from a report made on the kaolin deposit in 1901 by Dr. Heinrich Ries for the Kaolin Company of West Cornwall, Conn.

2 C. U. Shepard, Report on the Geological Survey of Connecticut, 1837.

CHAPTER II.

The Origin of Clays.

For a thorough understanding of the properties, value, and uses of clays, a knowledge of what clay is and whence it originated is necessary. The term "clay," as commonly used, is a general name for any plastic earthy material which can be molded into any desired shape. Clay, from the mineralogical standpoint, consists generally of the mineral kaolin, a compound of aluminum and silicon oxides and water, mixed with variable quantities of other products of disintegration and decomposition of rocks. The "clays" of commerce are all composed of a greater or less amount of kaolin mixed with fine particles of quartz and other minerals; and the proportions of this mixture depend upon the mode of origin of the clay in question.

Clays may be divided, according to their origin, into the following classes[1]:

I. RESIDUAL, formed by decomposition of rocks in situ.

II. TRANSPORTED, by
- *a.* Glaciers. Till or bowlder clay.
- *b.* Water. Alluvial, lacustrine, estuarine, and marine deposits, including shales.
- *c.* Wind. Loess (?) and adobe.

I. RESIDUAL CLAYS.

The term "residual" is applied to the material left as *residue* by the decomposition of rocks. All rocks, whether of igneous or sedimentary origin, are more or less subject to disintegration and chemical decomposition, according to the minerals of which they are composed, and the resulting residue is composed chiefly of the insoluble minerals, kaolin and quartz, with more or less red oxide of iron.

---

1 Other more elaborate classifications of clays have been proposed, consisting of several further subdivisions of the divisions here given; but, as the process of the forming of the clay is similar in all the subdivisions of each class, the classification offered here is considered sufficient.

All eruptive rocks are composed principally of varying percentages of silica, alumina, iron oxides, magnesia, lime, soda, and potash. The following analysis is given as an average chemical composition of granite: —

INSOLUBLE.		SOLUBLE.	
Silica, SiO_2	70.00	Ferrous oxide, FeO	2.50
Alumina, Al_2O_3	14.00	Magnesia, MgO	1.00
Ferric oxide, Fe_2O_3	1.00	Lime, CaO	2.00
Oxides of		Soda, Na_2O	3.50
Titanium, TiO_2		Potash, K_2O	4.00
Zirconium, ZrO_2	1.00		——
Phosphorus, P_2O_5			13.00
	——	Water, H_2O	1.00
	86.00		86.00
			——
		Total	100.00

Rain water, always carrying a small amount of carbon dioxide (CO_2), penetrates into the joints or seams and the cracks which have been made by frost action, and attacks the different minerals. Quartz, or crystalline silica, is undecomposable; the feldspars, consisting of potash, or soda and lime, with alumina and silica, are decomposed, the potash, soda, and lime going into solution as carbonates, the alumina uniting with silica and water to form kaolin, and the surplus silica mostly remaining as additional quartz. The dark constituents, principally mica and hornblende, more commonly become hydrated, and pass over to a dark green mineral, chlorite, a hydrous alumino-silicate of iron and magnesia, and to free quartz, while a part of the soluble constituents pass off as carbonates. If the water contains oxygen in solution, the dissolved iron is oxidized to the insoluble ferric oxide, and remains in the residual clay.

It is readily seen from these reactions that pure clay, or kaolin, practically never exists in nature, and that as a rule only those rocks rich in feldspars and free from dark, iron-bearing minerals, e. g., pegmatite veins and binary granites, can yield a white residual clay. As practically all igneous rocks contain some feldspar, they all can yield a certain amount of kaolin in their residual soil, but only the residual

products of pegmatite veins and occasionally of granites or gneisses have yielded kaolin of commercial importance.

As sedimentary rocks are derived from the disintegrated fragments and residual soils of igneous rocks, they also may contain clay and fragments of feldspar which were carried and deposited by streams before they could be decomposed. The brownstone of Connecticut is such a rock, consisting principally of quartz, feldspar, mica, and red clay cement. Shales are formed principally of fine particles of clay which was derived from residual soils, and, owing to its fineness, was carried by the water farther than the other mineral grains, and deposited in one mass. Limestones may contain a small amount of this clay as impurity. Thus, when sedimentary rocks in their turn are disintegrated and decomposed, they, too, will yield a certain amount of kaolin; but it is, save in the case of shales, generally insignificant. The kaolin at West Cornwall is unique in being the only commercially important deposit derived from a sedimentary rock. Undecomposed shales in many states are allowed to disintegrate and are then ground and used, the process simply returning the clay to its unconsolidated condition. This brief discussion shows that residual clay is rarely pure kaolin, even when decomposition is complete. The amount of true kaolin contained is known as the "clay base."

II. TRANSPORTED CLAYS.

As residual clays are mostly impure, the transported clays, derived from partially decomposed residual material, are naturally still more impure. Transported clays may be formed by three agents, which may act separately or conjointly: namely, glaciers, water, and wind.

A. GLACIAL CLAY OR TILL.

Glacial clay, till, bowlder clay, or hardpan, all different names for the same thing, is limited to the northern part of the country, and, commercially, is unimportant, especially in New England. During the Quaternary age of geological history the northern part of North America was elevated far above its

present level, the temperature was colder, and conditions favored a vast accumulation of ice several thousand feet thick in the region near Hudson's Bay. The ice, pressed out laterally at the base by its own weight, began to flow in all directions in the form of a great sheet, covering the whole of Canada, and the United States as far south as Long Island.

The surface of this region heretofore had consisted of decomposing rock and residual soil. The advancing ice sheet scraped away this loosened material, ground the rock fragments to a powder, which it used as an abrasive for grinding down and polishing the surface of the underlying bed rock. This mixture of fresh and decomposed material from different kinds of rocks was spread as a blanket over the surface of the country, varying in thickness from 0 to 50 feet, according to the contour of the bed rock surface. Rock ridges were left nearly bare, while the valleys were filled to a considerable depth. At various points resistance to the advance of the ice, such as a projecting ledge, caused the deposition of unusually large amounts of material, which the ice rode over and left as smooth, lenticular hills. These hills form the so-called drumlins or "hog-backs," so common in central Connecticut.

Till, from its origin, must consist not only of true clay, but mostly of more or less undecomposed rock material, partly reduced by grinding action to a fine powder, or "rock flour," and partly in fragments varying in size from mere pebbles to large bowlders. The aproximate percentages are gravel 25 per cent., sand 20 per cent., rock flour 40 to 45 per cent., and true clay less than 12 per cent. The chemical composition of course depends upon the composition of the rocks from which the material was derived.

B. CLAYS TRANSPORTED BY WATER.

All clays transported by water are derived from rock fragments, residual clay, or till, according to the formations through which the waters depositing the clay pass. The finest particles are only deposited where the water is deep or stagnant, as in alluvial or flood plains, swamps and marshes, lakes and estuaries, and in the deeper off-shore portions of the ocean.

1. *Alluvial Clays.* — The alluvial or flood plain of a river

is the flat, sometimes swampy, area through which it flows for a part of its course, and which is submerged in time of flood. As the water at first sweeps over the plain, it deposits only its coarser material; but, as the water spreads and flows more and more slowly, finer sediment is deposited, and last of all the finest particles are deposited in quiet water. This succession is repeated with every flood, gradually raising the level of the river valley; so alluvial clays are a mixture of sand, clay, and decayed organic matter, the latter resulting from the vegetation growing on the plain or from the sticks, leaves, etc., brought from the flood. The fire-clays of the Coal Measures have an origin analogous to that of alluvial clay, and their light color is due to the presence of vegetation, which, while growing, derived alkalies and lime from the clay, and, while decaying, reduced the iron to the soluble form which was removed by water.

2. *Lacustrine and Estuarine Clays.* — The clays deposited in lakes and estuaries are alike both in character and mode of formation. When rivers or streams empty into a body of quiet water, their velocity is checked, and they deposit their coarser materials, while the finest is carried farther and deposited in deep, quiet water. By long continuation of this process the lake bottom gradually rises, while the coarser materials advance into the lake as a delta, covering the clay beds already deposited, and slowly obliterating the lake.

3. *Marine Clays.* — Where rivers empty into the open sea, the fine material is carried out beyond the limit where wave action stirs the water. The dissolved salts in sea water have a flocculating effect on the clay particles, and incite a much more rapid deposition than that which takes place in fresh water. Clays deposited in the ocean are only available when elevated above sea level, generally in the form of shales.

All clays deposited by water, if overlain by a considerable thickness of sediments and compressed by their weight, lose water and become hardened into shale, which requires grinding and soaking to regain those properties peculiar to clay. Shale is a transitional form between clay and slate, the slate resulting from heat and pressure combined, which so alter its structure that it loses the properties of clay.

C. CLAYS DEPOSITED BY WIND — EOLIAN CLAYS.

In the Mississippi basin there is a peculiar deposit of great extent, known as the *loess*. This deposit is believed by some to have been deposited by wind, by others to have been laid down in water, and no explanation has yet given general satisfaction. In the arid region of the southwestern states there are extensive valley deposits of impure clay, called *adobe*, accumulated mostly by winds, which blow the waste of the adjacent mountains into the valleys.

CHAPTER III.

Geological History of the Connecticut Clays.

Pre-Glacial Conditions. — With the general knowledge of the origin of clays gained from the last chapter, it may be of interest to trace in some detail the origin of the Connecticut clays. At the close of the Paleozoic eon of geologic time, Connecticut consisted of an eastern and a western highland of crystalline rocks separated by a long intermontane valley, the valley of the Connecticut River, which extended from northern Massachusetts southward to the sea. During the Triassic era, which followed, the disintegrating detritus from the crystalline rocks was washed by rapid streams into the central valley, forming a deposit of great but unknown thickness. These sediments were coarse or fine, according to the varying conditions of deposition, and finally hardened into sandstone and shale. Their reddish brown color is due chiefly to the red residual clay which coated the grains of rock before transportation, and partly to the ferruginous clay that was deposited along with the grains, partially filling their interstices. While the sandstone was mostly deposited near the sides of the valley, the shale was laid down in the central portion, where its outcrops are now, by disintegration, or weathering, forming a red residual clay.

During the formation of these Triassic sediments, there were intermittent volcanic eruptions, which came up through the sediments and formed the areas of trap rock so common in the valley. The whole of New England was subsequently elevated, and the soft sedimentary rocks suffered extensive erosion, leaving the more resistant trap in ridges. At the same time the crystalline rocks of the highlands were undergoing weathering, and, in places protected from erosion, were being decomposed and kaolinized to considerable depths. It was during this period that the West Cornwall and other kaolin deposits in the western highlands were formed. The frac-

tured character of the feldspathic rocks and the pegmatite veins enabled water to penetrate and kaolinize them to much greater depths than the adjacent, more resistant rocks.

Advance of the Ice Sheet. — Such were the conditions up to the arrival of the great glacier, which covered all New England, and terminated at Long Island. The work of the glacier has already been described, and it is sufficient here to say that all the residual soil of both valley and highlands, save at those places where deep deposits of kaolin were protected by resistant rock, was scraped away and redeposited as till over fresh rock surfaces. The kaolin deposits are in reality only the bottom remnant of deposits once much larger. It is probable that kaolin deposits existed in the eastern highlands, but were destroyed by the glacier.

The till of the highlands, like that all over New England, is of a bluish gray to buff color, and usually forms thin coverings over the rock. It is too full of bowlders to be of commercial value as a clay. The till in the valley is an unusual type. It is reddish brown in color, owing to the fragments of shale and sandstone of which it is principally composed, and which were derived from Massachusetts and northern Connecticut. These fragments, especially those of shale, are, owing to their softness, mostly small pebbles and grains, but some large stones are found, accompanied by bowlders of the Triassic trap and occasionally of quartzite and schist.

Retreat of the Ice Sheet. — A change to a warmer climate, perhaps correlated with a subsidence of the northern part of the continent, now caused the melting and retreat of the ice sheet. The retreat was not steady, but interrupted by a series of halts, which are marked by high deposits of cross-bedded gravel in the form of kames and short deltas, deposited by swiftly moving water among the stranded blocks of ice that fringed the retreating glacier. These deposits, which served as obstructions to drainage from the ice, and gave rise to temporary lakes in which the clays were deposited, occur in the southern part of Cheshire; along a broken line through Middletown, Berlin, and Plantsville; at Rocky Hill, in Wethersfield, through South Manchester, and at Clayton; and in Massachusetts north of Holyoke.

The subsidence of the land gave little or no head for the waters issuing from the ice front, and, in many cases, the deposits formed at ice halts served to dam the channels and hold back the waters. The valley of the Quinnipiac, depressed below sea level, became a long, deep estuary in which the fine clay derived from the material in and under the ice was deposited. This deposition probably began while the ice front was halted in South Cheshire, the coarser material depositing at the ice front and the clay in the Quinnipiac estuary.

The ice then retreated a few miles northward and established a new front which extended through Plantsville, Berlin, and Middletown. At Plantsville the glacial waters were held back by the frontal deposits at South Cheshire, and formed a lake in which the Milldale brick clay was deposited. The gravel and clay along the Connecticut River south of Middletown were formed during this period.

The conditions regarding the next deposits have not yet been conclusively worked out, but the evidence at hand strongly suggests another ice halt at Rocky Hill, where a large gravel plain, the present altitude of which is 180 feet above sea level, was built southward along the Connecticut valley. The high level of this plain suggests that it formed while ice still lingered at Middletown and along the valley of the Sebethe River, as the highest indication of shore line to the south of the plain is only 120 feet above sea level, 60 feet lower than the maximum height of the plain. When the ice disappeared from Middletown and the valley of the Sebethe, the outlet of the waters was lowered to a level which is now 80 feet above the sea, and the lake was formed in which the brownish red clays of Berlin, Middletown and Cromwell were deposited.

The next retreat of the ice was from Rocky Hill into Massachusetts, and the glacial waters, held back by the kames and high gravel plain at Rocky Hill, spread over the entire Connecticut River valley from Wethersfield northward into Massachusetts. The traces of the original shore line are hidden by the vast quantities of sand and gravel that were washed in from east and west, and narrowed the lake. The level of the clay surface, however, is very uniform. It is somewhat above the 80 foot contour line at the northern boundary of the state, and gradually lowers southward, until, south of Hartford, it

is near the 70 foot line. This slight difference may be accounted for, partially at least, by the depression of the continent to the northward at that time.

There is evidence of a temporary channel extending from Newington station, southward along the Hartford division of the Consolidated Railroad to the lake bed at Berlin. This channel probably formed the outlet of the great lake until the re-elevation of the land, and connected this lake with the Berlin lake, the waters finding their final exit along the Sebethe valley and through Middletown. The channel shows remnants of shore lines at, or a little above, the 80 foot contour, and the slight difference of from 10 to 15 feet between this line and the surface of the clay south of Hartford, shows that the great lake was nearly filled with sediment at the time of its final draining.

It is doubtful to which of these two last mentioned lakes the clay at Clayton belongs. From the general topography, it might have formed in a long arm of either lake, but its undulating character and high level destroy all direct evidence. The color of the clay, however, as well as the high gravels which have been built out over it, suggests that it was formed during the ice-halt at Rocky Hill. The undulating character of the clay beds is apparently due to the weight of the thick deposit of overlying gravel, which squeezed the clay from under it and caused the beds beyond to rise and make room for the displaced clay.

Color of the Clays. — The difference in color between the clays of the northern lake and those of the other lakes is very significant. The material included in the ice which stretched over Connecticut was mostly the red Triassic material; that included in the ice north of Holyoke, Mass., was principally the ground-up débris from the older rocks of northern Massachusetts, New Hampshire, and Vermont, as the ice at this point had ridden over only a few miles of Triassic sediments. Clay from these rocks is characterized by its bluish color. The data from borings, which show the clay, especially in the vicinity of Hartford, to become red at depths of from 15 to 20 feet below the clay surface, also coincide with this conclusion, as the ice, while retreating from northern Connecticut, would still be giving up débris from Triassic material, which would

be covered in time by the clay derived from the rocks north of the Triassic area.

Lamination of Clays. — The interlamination of the fine layers of quicksand with those of strong clay was caused by alternations between slightly moving and quiet water. Prof. B. K. Emerson [1] explains this alternation by the successive seasons of melting and freezing. In the warmer, melting season, the water flowed in greater quantity from the ice front, built out deltas which now form the high coarse gravel plains along the margins of the lake basins, carried the finest sand out into deep water and deposited it, while the minute clay particles remained in suspension. In the winter months, when the flow of the waters practically ceased, the clay particles were deposited over the sand, to be covered again by the sand deposited during the next melting season. By noting the number of these alternations, some estimate could be made of the number of years that elapsed during the deposition of the clay beds.

Undulations and Contortions of Clay Layers. — The cause of the undulations and contortions often seen in these clay deposits is generally attributed to a re-advance of the ice sheet. It has been shown by Prof. Emerson that several re-advances took place near Northampton, Mass., as beds of till alternate with beds of sand and clay, the latter compressed and contorted by the pressure of the over-riding ice, and sometimes showing slaty cleavage;[2] but no such direct evidence has been found in Connecticut. In some of the Berlin clay banks, the clay is so highly contorted that the sand and clay layers are all jumbled together. The clay is exposed at the surface, and there is no sign of till. Some great force must have produced such contortions, and it is possible that a short re-advance of ice took place before the deposits marking the Rocky Hill halt were made; but it seems impossible that the later waters from the great northern lake, which entered the Berlin lake at this place, could have had sufficient velocity to erode all deposits which might have furnished evidence.

At North Haven there is a layer of clay about two feet thick, very highly contorted, between considerable thicknesses of undisturbed layers. This instance offers no more satisfac-

1 Holyoke Folio (No. 50), Geologic Atlas, U. S. Geol. Survey.

2 Loc. cit.

tory evidence than that at Berlin, and no explanation will be attempted.

The large undulations at Clayton due to the downward pressure of the overlying gravel have already been explained. Slight undulations in clay at the surface are sometimes caused by tree roots which, in growing, push the clay slightly in all directions; but most slight undulations are probably due to the general settling of the clay. The amount of settling would be greatest in the deeper parts, where the pressure from the overlying beds is greatest. Where the floor of the deposit is irregular, the variations in shrinkage will result in slight undulations, or even slight slips or faults. Examples of both kinds have been observed in the Connecticut clays, and it is also noteworthy that these undulations are most pronounced at the surface, and gradually diminish towards the foot of the exposure.

Joints. — Joints, or vertical seams, are also common in some clay banks, especially where the clay is dry. They are caused by the shrinkage of the clay from loss of water, and are analogous to the cracks seen in dried mud. These joints divide the clay into roughly hexagonal blocks, and facilitate mining, especially when the method of "undermining" is employed.

Clay Concretions. — Very often certain layers in clay banks are crowded with concretions of various size and shape, known as "clay-stones" or "clay-dogs." These concretions consist of particles of clay and fine sand cemented together by carbonate of lime. The lime was originally in minute mineral particles deposited along with the clay, which have since been attacked by the carbon dioxide in the water. The lime was dissolved, carried along the more porous layers, and deposited at points where the solution became supersaturated. The normal shape of such concretions is spheroidal, but is modified by the thickness of the layer in which it lies, and the directions from which the lime carbonate is supplied. Several of these concretions sometimes grow together, forming curious shapes. They are still forming. These concretions, when small, are harmless; but when large, and present in great quantity, they may render the clay worthless.

Bowlders and Pebbles in Clay. — It is not uncommon, in working a clay pit, to find pebbles and even bowlders of con-

siderable size embedded here and there in the fine clay. The only plausible explanation of their presence is that they were enclosed in, or carried upon, blocks of floating ice that broke away from the ice-front, and dropped when the ice melted.

Effect of Post-Glacial Conditions on the Clay Deposits. — It has already been mentioned that, during the retreat of the ice, gravels and sands were deposited along the margins of the great northern lake in the form of deltas, and had begun to fill it. These deposits are characterized by cross-bedded layers, which dip from the lake margins towards the Connecticut River, and, at many clay pits, lie directly and abruptly upon the clay. When, after the final retreat of the ice-sheet, the land surface was reëlevated to the north, the streams received greater velocity, and brought greater quantities of gravel and sand into the lake. At the same time, the waters of the lake found a more direct exit over the lowering barrier at Rocky Hill, rapidly cut an outlet channel through the loose gravels there, and soon drained the lake. The Berlin lake, having now lost its supply of water, also disappeared. The Connecticut now resumed its course through the deposits of the drained northern lake, and developed terraces at intervals as it cut its valley deeper and deeper, until it finally developed its present flood plain, while the tributaries which formerly built out the large gravel deposits, now had to cut down through these deposits to keep at the same level as the Connecticut River. These tributaries, too, were able in some cases to develop terraces of considerable height. The formation of these terraces has a considerable influence on the location of clay pits, as those dug into the sides of terraces can be so leveled that they will be self-draining, and save the expense of keeping a pump.

The downward cutting of the larger streams of the region has practically ceased now, leaving the clay area of northern Connecticut as a dissected plain. The draining of the Milldale Lake and other smaller lakes was a similar process to that of the great northern lake, though less interesting. The reëlevation of the land also raised the Quinnipiac clay above sea level. Present conditions show that the coast of Connecticut is now slowly sinking again, and black mud, consisting of fine clay and organic matter, is slowly accumulating in the estuaries.

CHAPTER IV.

The Chemistry of Clays.

Pure clay consists of the mineral kaolin, a hydrous silicate of alumina, which corresponds to the chemical formula $H_4 Al_2 Si_2O_9$, or $2H_2O + Al_2O_3 + 2SiO_2$. Its percentage composition is:

Silica, SiO_2	46.5
Alumina, Al_2O_3	39.5
Water, H_2O	14.0
Total	100.0

There are two varieties of this mineral: *kaolinite,* which crystallizes in white scales with satin lustre, and ordinary *kaolin,* which is partly crystallized and partly compact. The latter variety is always more or less impure, owing to the presence of quartz, iron oxide, and other products of rock decomposition. Kaolin is a soft mineral, scratched by the finger-nail, and has a specific gravity of 2.6. The color of the pure mineral is white, but varies with impurities through yellow, brown, blue, and red. There is also present in practically pure clay a massive mineral, *pholerite,* very similar to kaolin, but sometimes containing as much as 15 per cent. water. No distinction between these minerals is necessary, however, for all practical purposes.

Some residual, and a few transported, clays, as shown in Chapter II, are very free from harmful impurities; but most clays, especially transported clays, are full of foreign matter, some consisting of from two-thirds to three-quarters impurities. The relative proportion of impurities depends, of course, upon the source whence the clays were derived. Glacial clays, for example, in the limestone regions south of the Great Lakes are very high in lime and magnesia; while those derived from the crystalline rocks of New England are high in silica, iron, and alkalies, with often considerable amounts of lime and magnesia.

The physical properties of a clay are so dependent upon its composition and chemical properties, that many of them may be largely discussed in this chapter, and simply reviewed in the following chapter on physical properties. The chemical properties are governed by the mineral and chemical composition. The chemical constituents commonly found in clay are silica, alumina, iron oxides, lime, magnesia, the alkalies (soda and potash), titanic oxide, water, carbon dioxide, various sulphur compounds, and organic matter.

Silica, SiO_2. — Silica is found in all clays, and may occur in three different forms: in the kaolin or clay base, as pure quartz sand, and in the different silicate minerals that occur as impurities in clays. Silica in kaolin needs no further consideration. Though quartz is considered an impurity in clay, it is an essential constituent for the manufacture of many different products. It occurs in small, angular, or rounded, grains. Its chief properties are (1) to diminish the shrinkage and prevent warping and cracking, which is liable to take place in rich or strong clay; (2) to diminish the plasticity, which is often too great in a pure clay for a molded form to retain its shape; (3) to raise the point of fusion, which in many clays would be so low as to render the clay useless. The degree of the influence of free silica depends upon the amount in the clay. Some flint clays in Missouri contain as little as 0.5 per cent. quartz, while the most impure clay from the same state contains 86 per cent.[1] An analysis of New Jersey clay showed only 0.2 per cent.[2] The Connecticut brick clays contain, as a rule, over 50 per cent. silica; the kaolin at West Cornwall 47.50 per cent. Fifty per cent. generally is considered very high.

The fact that quartz is infusible and expands slightly in all directions when heated explains its property of diminishing shrinkage. Thus a large percentage of quartz means a low precentage of shrinkable material, while the actual amount of shrinkage is in part counteracted by the expansion of the quartz. Addition of a sufficiently large amount of quartz to clay has been known to cause expansion during burning.[3] Of

1 Geol. Surv. of Missouri, Vol. XI, 1896, p. 49.
2 Geol. Surv. of New Jersey, 1878, p. 273.
3 Geol. Surv. of Michigan, Vol. VIII, 1900 to 1903, p. 11.

course, the less the shrinkage, the less the danger of warping and cracking.

When clay is burned, the other impurities, particularly the alkalies, fuse at a comparatively low temperature, and form a cement which binds the infusible grains of sand together into a firm, compact mass. Silica fuses at about 2,800° F., a point somewhat lower than the fusing point of pure kaolin; but 2,800° F. is a higher heat than most refractory clays have to withstand. Silica, however, in large amounts, and in the presence of free bases, as alkalies, lime, or a considerable quantity of iron, tends to form with them fusible silicates, which lower the fusing point of the clay.

Silica in grains of silicate minerals plays a passive part, as these minerals have special fusing points. These fusing points range from the vicinity of 1,900° F. upwards, and are all below the heat that a fire-clay should withstand. Below their fusing points, these mineral particles behave the same as quartz by diminishing shrinkage and plasticity; above their fusing points they act as fluxes.

Alumina, Al_2O_3. — Alumina, besides being an essential constituent of kaolin, occurs in grains of feldspars, micas, hornblende, pyroxene, and the alteration products of these minerals. Its properties, therefore, depend upon the properties of the minerals containing it. It is, however, safe to assume that clays high in alumina are refractory, unless the percentage of fluxes is unusually high. Thus the Connecticut brick clays, though carrying from 17 to over 22 per cent. alumina, are very high in fluxes (15 to 19 per cent.), and are easily fusible; while the kaolin at West Cornwall, with 37.40 per cent. alumina and only 2 per cent. fluxes, is very refractory.

Iron Compounds. — Iron may justly be called the most important impurity in clay, as its presence or absence is the principal factor in determining the use of the clay. Iron oxides exist in nearly all clays, and range from less than 1 to 15 per cent. and perhaps higher. Iron in clay occurs in a number of minerals, either in the protoxide state (FeO), or the sesquioxide state (Fe_2O_3). The protoxide is found principally in magnetite, ilmenite, siderite, in unaltered, and sometimes in altered, ferro-magnesian silicates; the sesquioxide in hematite and

limonite, which may occur alone or as minute specks in altered silicates. Most of these minerals in the clay are in fine grains; but limonite, the hydrated sesquioxide, generally forms a film around grains, or becomes closely united with the kaolin, in either case giving the clay a brownish color. Siderite, the carbonate, occurs in concretions, similar to clay-dogs, and is known as "clay-iron-stone."

The chief property of iron in clay is its influence on the color of both raw and burned clay. Many clays when mined are of a black, blue, or grayish color, due to the protoxide, with perhaps some organic matter, while others are yellow, brownish, or reddish, owing to the sesquioxide. Clay banks are often of yellowish or buff color near the surface, and bluish or gray below, the difference being due to the superficial oxidation of the protoxide to sesquioxide. The presence of the protoxide in burned clay gives rise to a dark gray to black color, often seen in the sagged and partially melted bricks in the arches of kilns; the sesquioxide gives the burned clay a salmon to deep red color; the depth of the color in each case depending on the amount of the oxides present and on the degree of burning.

It takes only a little iron to influence the color of a burned clay. Chinaware clays should contain less than 1 per cent. Clays with less than 5 per cent. will burn to a distinct, but not deep red; while clays carrying from 5 to 8 per cent. give a deep cherry-red color. Higher percentages than this do not increase the redness to any appreciable extent. It matters not whether the iron in the raw clay is in the ferrous (protoxide) or ferric (sesquioxide) state; for, if properly burned, with free access of air, the iron will all finally take the form of the anhydrous red oxide. If, however, there is not free access of air, or the flame is smoky, no iron is oxydized, but the ferric oxide, Fe_2O_3, is reduced to ferrous, FeO, turning the burned clay black. Too much heat, or enough to begin to fuse (vitrify) the clay, also begins to reduce the iron. This is what takes place in the half-melted, black bricks in the arches of scove kilns, although the black color may be intensified by fine cinders and smoke which stick to the burning clay.

Besides influencing the color of clay, iron is an important

fluxing agent. Ferric oxide, on account of its higher fusing point, is not as strong a flux as ferrous oxide. Just how much iron is detrimental to a refractory clay has been a disputed question. Some of the most refractory clays known average over 2 per cent., but refractory clays, as a rule, should not carry over 2 per cent.[1]

Iron, when alone, has been found, according to some writers, the least fusible of the usual impurities; but its fluxing powers are increased by the presence of the other bases. According to other writers, iron is a stronger flux than lime or magnesia. In the tests on the New Jersey clays, samples containing different proportions of iron and potash were fused; and the iron, when exceeding 2.5 per cent., appeared to be more detrimental to refractoriness than did the potash.[2] Clays containing 5 to 15 per cent. of iron fuse at much lower temperature than do other clays, and large excesses of ferric oxide tend to cause blistering in burning,[3] probably on account of the formation of steam from the chemically combined water.

The sulphide of iron, *pyrite* or *marcasite,* the sulphate, *melanterite* or *copperas,* and the carbonate, *siderite,* deserve special mention. Pyrite may occur as nodules (" sulphur balls "), as cubic crystals, or as fine grains disseminated throughout the clay. It is a strong fluxing agent, and is readily decomposed when heated, the sulphur burning to a gas, and the iron becoming ferrous oxide, a strong flux. Sulphur balls are detrimental, as they would cause fluxing in certain spots, while the escaping sulphur gas, SO_2, would unite with more oxygen and water, forming sulphuric acid, which would act on some of the constituents, forming sulphates. These sulphur balls, or sulphur stones, if large, can be removed during preparation of the clay, or, if small, may be crushed in a disintegrator, and disseminated throughout the clay during tempering. When small crystals or grains are not crushed, they produce little black spots of fused iron silicate, such as are often seen in fire-brick. Some of the New Jersey clays used in Connecticut for

1 E. Orton, Jr., Ohio Geol. Surv., Vol. V, 1884, p. 654.

2 G. H. Cook, Geol. Surv. New Jersey, Rep. on Clays, 1878, p. 303.

3 H. Ries, Geol. Surv. Michigan, Vol. VIII, 1900 to 1903, p. 10.

the manufacture of stoneware and fire-brick must be crushed before using to break up the small pyrite crystals.

Pyrite in clays only exists where it has been reduced from the sulphate of iron by organic matter, and where oxidizing agents are absent. Such conditions are practically limited to the fire-clays, especially of the coal-bearing regions. In other clays, for example those in Connecticut, what may have originally been pyrite while in the parent rock, has long since been oxidized either to the sulphate, or, more probably, to the hydrous oxide, limonite.

Iron sulphate can be detected by its characteristic inky, astringent taste. It causes a white efflorescence, and, if in considerable amounts, renders the clay worthless.

Siderite ("clay-iron-stone"), the carbonate, occurs as concretions similar in origin and structure to the "clay-dogs." As was the case with pyrite, it is decomposed by heating, forming ferrous oxide and carbon dioxide. The concretions, if large, should be removed, as their effect on the color and fusibility would be similar to that of pyrite nodules, and the escaping gas would blister the ware. When in small concretions, well disseminated, the carbonate is not harmful.

Lime, CaO. — Lime is also of great importance as a coloring and fluxing agent, especially in limestone regions, where the glacial clays are very high in lime. Lime occurs as carbonate in ground fragments of limestone and in "clay-dogs," and in several silicates, especially the plagioclase feldspars and ferro-magnesian minerals. Lime, in either state, burns to a pure white color, and, when in sufficient amount, neutralizes the coloring effect of iron, by forming with the latter a double silicate which produces buff and cream-colored effects common to many clays of the Great Lakes region. The proportion of lime to produce this neutralization should be at least three times as great as that of iron. Some clays of the Great Lakes region contain as much as 25 per cent. lime, but high grade clays should have less than 2 per cent.

Although the carbonate of lime is fusible only at very high temperature, it readily loses its carbon dioxide, and can then unite with free silica. If sulphur is present and has formed sulphuric acid, the acid will react with lime carbonate, forming

lime sulphate, which is soluble, and will cause efflorescence on the raw, or on underburned clay, if the temperature is not sufficient to decompose the sulphate. As little as 0.1 per cent. of the sulphate is sufficient to cause efflorescence.

This efflorescence can be avoided by mixing thoroughly with the clay a proper proportion of barium chloride or carbonate, the former as a solution, the latter, which is insoluble in water, as a very fine powder. The reaction which follows gives insoluble barium sulphate and lime carbonate.[1] For every gram of lime sulphate there should be added 1.45 grams of barium carbonate, or 1.53 grams of barium chloride, with a little excess for safety. Thus, to a pound of clay containing 0.1 per cent., or 0.4 gram, of lime sulphate there should be added 6 or 7 grams of barium carbonate, or 7 grams of barium chloride. With barium carbonate at 2½ cents a pound, and a green brick weighing 6 to 7 pounds, the cost per 1,000 brick would be increased by about $2.50 (not counting any extra labor of mixing, etc., which could be done directly in the pug mill). Barium chloride would increase the cost only 32 cents per 1,000, and gives a quicker reaction. This process, adequate for other soluble sulphates, would increase the selling price, but would insure a permanent red color.

If an underburned brick still contained any lime carbonate, and was permeated by water carrying carbon dioxide, as all rain water, especially in large cities, does, the carbonate would suffer solution, and be redeposited as a white coating on the surface. Proper handling of the clay and thorough burning should expel all the carbon dioxide, and allow the lime to flux with the silica.

"Clay-dogs" are not harmful in thoroughly burned ware, unless of large size. Large nodules burn to quick-lime, which takes on moisture from the air, and swells, or bursts, the brick.

Lime is very detrimental to refractory clay. If, however, in a coarse, dense clay, the iron and alkalies are less than one per cent., lime and magnesia may together equal 2 per cent.; but usually they should be less than one per cent.[2]

Clays high in lime and magnesia tend to fuse, or vitrify,

---

1 H. Ries, Geol. Surv. of Michigan, Vol. VIII, 1900 to 1903, p. 8.
2 Wheeler, Missouri Geol. Surv., Vol. XI, 1896, p. 71.

suddenly, and are undesirable where incipient fusion is necessary, as in paving brick. Lime in large amounts diminishes shrinkage during burning.

Magnesia, $Mg\,O$. — Magnesia is similar to lime both in its general occurrence and properties, and what has been said of lime is practically true of magnesia. Magnesium carbonate, however, is not commonly found in nodules.

Alkalies, $Na_2\,O$, and $K_2\,O$. — The alkalies in clay are principally potash and soda; lithia is rarely present, while ammonia is readily absorbed by clay and is largely responsible for its characteristic odor,[1] but is quickly driven off on heating.

The chief sources of soda and potash are the feldspars and micas. These alkalies are present in nearly all clays, varying from a mere trace up to about 10 per cent. They are the strongest fluxing impurities in clay, and are especially desirable in clays used for the manufacture of vitrified ware, since, by fusing at a low temperature, and in feldspars fusing slowly, they cement the grains into hard, dense, impervious body.

According to Wheeler,[2] soda is a stronger flux than potash, but the combination of the two is worse than either alone. Their fluxing power is further increased by the presence of the other bases, which favor the formation of a double or complex silicate. Lithia has properties similar to those of potash, but is too rarely present to be of importance.

The influence of alkalies on refractory clays will be best understood by the following paragraph quoted from Cook.[3] "Opinions differ as to the amount of potash which may be positively damaging in a fire-clay. Snelus states that about one per cent. confers so much fusibility as to render them unsuitable at high temperatures.[4] Bischof found that four per cent. potash in a silicate of alumina without any other bases could be fused at the melting point of wrought iron. . . . Clays containing two to three per cent. of potash are said to stand well at high temperatures. The most carefully made analyses of the more noted and best fire-clays of this country and Europe, do not generally show more than two per cent.

1 H. Ries, North Carolina Geol. Surv., Bull. 13, p. 16.
2 Missouri Geol. Surv., Vol. XI, 1896, p. 148.
3 Geol. Surv. of New Jersey, Rep. on Clays, 1878, p. 295.
4 Jour. of the Iron and Steel Institute, 1875, p. 513.

of potash, and the greater number do not contain one per cent. of alkalies. So far as the clays of this state (New Jersey) have been tried, those which are found to have one and a half to two per cent. and upwards of potash have not proved to be good fire-clays. And yet they are otherwise rich and tolerably pure clays. The potash alone appears to explain their low refractory property."

Alkalies have little or no influence on the color of burned ware, but it is said that their presence in large amount tends to turn the red color produced by iron to a brownish tint. The sulphates and chlorides if present will cause a white efflorescence on raw clay, but fuse at too low a temperature to exist in well burned brick.

Titanic Oxide, TiO_2. — Titanic oxide is generally present in clays in small amount. It is much like silica in its behavior, but is not so refractory. When in large amount, 6 to 10 per cent., it has a distinct fluxing action.

Water, H_2O. — Water in clay is present in two forms, mechanically included, or hygroscopic, and chemically combined. Water in the former condition exists in the clay when mined, but is largely expelled by drying in the air. To this water the plasticity of clay is largely due. Included water is sufficiently abundant in some clays, as in the Connecticut brick clays, to allow them to be ground and molded without previous soaking. When the water has evaporated, the clay becomes hard and brittle, but will regain its plasticity upon addition of water. The loss of this water causes a certain amount of shrinkage, which varies with the richness of the clay. If the drying is too rapid, the surface of the clay will shrink and harden sooner than the inner portion, and crumbling or scaling will result.

In burning clay the mechanically inclosed water is expelled at 212° F., the boiling point of water. If the temperature is too rapidly raised at the start, the outer portions of the clay will become hard and impervious before the water can all be driven from the inner part. The imprisoned water then changes to steam, and the resulting expansion swells or bursts the clay. This is one cause of swelled brick. The first, or "water-smoking" stage of the burning, therefore, should be

very slow to allow all the mechanically included water to escape through the pores of the clay.

The chemically combined water is an essential part of the clay base, as well as of certain other hydrous minerals, as limonite and chlorite, which may be present. This water is only expelled at red heat. When it is driven off, the clay loses plasticity for good. The escape of the chemically combined water may also cause swelling and bursting of the clay unless the temperature at red heat is kept uniform for a time, and then raised very slowly. By the loss of chemically combined water, the platy structure of the clay base is destroyed, the particles become indistinguishable, and the clay becomes a stony mass, which increases in density as the temperature is raised.

Carbon Dioxide, CO_2. — Carbon dioxide is the gas arising from the breaking down of carbonates by heat or the burning of organic matter. The gas itself is harmless, unless present in very great amount or hindered from escaping, when its expansion, like that of steam, will swell or burst the clay.

Sulphur Dioxide, SO_2. — Sulphur dioxide is derived from the oxidation of sulphur from sulphides or from the breaking down of sulphates, which are mostly dissociated at high temperatures. It readily unites with oxygen and steam, forming sulphuric acid, which attacks the alumina and other bases in clay very strongly, and, when in considerable amounts, causes a blistering of the clay. Its action is detrimental only when it is derived from minerals of considerable size. When disseminated throughout the clay, its action is uniform and not noticeable. It may, however, form sulphates which, in clay not burned to the temperature at which they decompose, will in time leach out and whiten the surface of the burned product.

Organic matter. — Organic matter is present in all clays to a greater or less extent, either as decaying vegetable matter at and near the surface, or in fine carbonaceous particles which have resulted from matter deposited in the layers of the clay. It is a strong coloring agent, giving to raw clay colors which vary from gray to black according to the degree of color produced by iron and other coloring agents. The

black mud in the marshes along the coast, and the black color of many slates, is due to organic or carbonaceous matter. Organic matter is easily driven off by heating, and has no influence on the color of the burned clay, unless, owing to an insufficient supply of air, it should reduce the iron and aid in producing a black color. The presence of organic matter in raw clay may so obscure the other coloring agents that it prevents a prediction of the color to which the clay will burn. Thus, while the clay of northern Connecticut, colored blue by ferrous oxide, burns to a deep red, there are some clays, colored blue by organic matter, that burn white.

MINERALS IN CLAY.

The properties of minerals in clay depend upon their structure and composition. All but kaolin and water, that is all the coarser grains of foreign matter, tend to lessen the plasticity. Some finely ground mineral matter possesses a certain degree of plasticity when wet, but it lacks cohesive strength on drying. The chemical properties depend upon the chemical constituents already discussed. It should also be borne in mind that the fusing point of a mineral is often lowered by the presence of other more fusible minerals. Even silica, which alone fuses at 2,800° F., is easily fused at about half that temperature when mixed with an equal volume of sodium carbonate. The fusing point of a clay then, is largely influenced by the most fusible mineral present. It remains only to see a list of the minerals found in clays, with their chemical composition, to gain a general understanding of their influence.

Name	Composition			
	Fluxes	Alumina [1]	Silica [2]	Volatile Matter
Kaolin		Al_2O_3	$2SiO_2$	$2H_2O$
Quartz			SiO_2	
Feldspars				
Orthoclase	K_2O	Al_2O_3	$6SiO_2$	
Albite	Na_2O	Al_2O_3	$6SiO_2$	
Oligoclase	$\left\{\begin{matrix} 3(Na_2O \\ CaO \end{matrix}\right.$	Al_2O_3 Al_2O_3	$\left.\begin{matrix} 6SiO_2) \\ 2SiO_2 \end{matrix}\right\}$	
Anorthite	CaO	Al_2O_3	$2SiO_2$	
Zeolites	$\left\{\begin{matrix} CaO \\ Na_2O \\ K_2O \end{matrix}\right\}$	Al_2O_3	3 to 4 SiO_2	2 to 6 H_2O
Micas				
Muscovite	K_2O	$3Al_2O_3$	$6SiO_2$	$2H_2O$
Biotite	$K_2O + 2\left\{\begin{matrix} FeO \\ MgO \end{matrix}\right\}$	$2Al_2O_3$	$6SiO_2$	H_2O
Magnetite	Fe_3O_4			
Hematite	Fe_2O_3			
Limonite	$2Fe_2O_3$			$3H_2O$
Siderite [3]	FeO			CO_2
Pyrite, Marcasite [4]	FeS_2			
Calcite [3]	CaO			CO_2
Dolomite	$CaO + MgO$			$2CO_2$
Chlorite	$5\left\{\begin{matrix} Mg \\ Fe \end{matrix}\right\}O$	Al_2O_3	$3SiO_2$	$4H_2O$
Epidote	$4CaO$	$3\left\{\begin{matrix} Al \\ Fe \end{matrix}\right\}_2O_3$	$6SiO_2$	H_2O
Rutile			TiO_2	
Ilmenite	FeO		TiO_2	
Sulphates soluble in water				
Gypsum	CaO			$SO_3 +$ $2H_2O$
Alum	K_2O	Al_2O_3		$\left\{\begin{matrix} 4SO_3 + \\ 24H_2O \end{matrix}\right.$
Epsomite	MgO			$\left\{\begin{matrix} SO_3 + \\ 7H_2O \end{matrix}\right.$
Sodium sulphate [5]	Na_2O			SO_3
Potassium sulphate [5]	K_2O			SO_3

[1] Including isomorphous Fe_2O_3.
[2] Including TiO_2.
[3] Loses CO_2 at red heat.
[4] Readily burns, giving off S, which oxidizes to SO_2.
[5] Sodium and potassium sulphates usually occur with sulphates of ammonium, calcium, or magnesium as double salts.

CHAPTER V.

The Physical Properties of Clay.

Several of the physical properties of clay, especially plasticity, shrinkage, color, and fusibility, have been already touched upon in connection with the chemical properties, and this chapter is intended to group together the facts already known, and in addition to discuss those properties which are independent of chemical properties. Physical properties may be conveniently grouped under the following headings:

PURELY PHYSICAL.	PHYSICAL AND CHEMICAL.
Structure.	Odor and Taste.
Hardness.	Shrinkage.
Feel.	Color.
Homogeneity.	Fusibility.
Density.	
Fineness of Grain.	
Strength.	
Slaking.	
Plasticity.	

Structure. — The structure and texture of a clay are largely dependent on its origin and consequent degree of purity, and are important chiefly because of their influence on other properties. Kaolin is a more or less compact mass, with no definite structure, such as cleavage or lamination; but clays of sedimentary origin often contain distinct layers of sand alternating with clay, and are well laminated. Many dry clays are jointed into polygonal blocks, which facilitates mining by the undermining method. Some clays are so dry, tough, and hard as to require blasting; others so soft as to be easily dug from the bank with a spade. The chief importance of the structure, then, is its influence on the methods of mining the clay.

Hardness. — Pure, compact kaolin has a hardness of 2 to 2.5; that is, it can be scratched by the finger-nail. Although, when moist, it is soft and generally plastic, the individual par-

ticles nevertheless possess their normal hardness. The hardest mineral impurity in clay is quartz, with a hardness of 7, sufficient to cut glass. The more abundant this mineral is, the harder will be the clay. The effect of hard impurities is felt in the wear of the machinery. The coarser and more siliceous the clay, especially if not soaked, the sooner and more often will the parts of the machine need to be renewed.

When clay is burned, the hardness increases as the clay shrinks. At the point of incipient fusion, when the individual grains have united, it is harder than glass, and, at complete fusion, it is nearly or quite as hard as quartz.

Feel. — The feel of a clay is found by rubbing a moistened piece between the fingers, or the teeth. The fine, pure, and plastic clays have a smooth, slippery feel, while the coarser and more impure clays are more or less gritty. Some very pure clays, however, the flint clays, are not plastic, and lack this greasy feel.[1] The feel gives a rough determination of the coarseness of a clay, its plasticity, and its consequent ability to be molded without cracking. Feel is a rapid method, convenient for out-of-door use, and sufficiently accurate for all practical purposes.

Homogeneity. — Clays vary from a practically homogeneous mass, as in many kaolins, to widely varying laminated clays, with coarse and fine layers. Homogeneity is important only in clays used for finer grades of work, where lack of homogeneity would cause cracking in drying and burning, and irregularities in shrinkage, and would interfere with the molding. In brick clays homogeneity is not important, but in higher grades of work, most clays have to be washed before they can be used.

Density. — The density of a clay depends largely upon the impurities present. The specific gravities of quartz and feldspar, the most common impurities, range from 2.55 to 2.75, while that of kaolin is from 2.60 to 2.63; so their presence does not alter the value of the density of solid matter. The presence of a large amount of quartz will, however, tend to raise the specific gravity, as it has not so strong an attraction for water, and the proportion of solids to water is increased.

1 Wheeler, Missouri Geol. Surv., Vol. XI, 1896, p. 80.

Most superficial clays possess a considerable quantity of water, and have an average density of 2.00 or a little less. The density is largely influenced by the pressure of overlying material which squeezes out the included water. Superficial clays from Missouri range in density from 1.69 to 2.17, with an average of near 2.00, while the potter's and fire clays from the Coal Measures, that have usually been overlain by several hundred feet of rock, range from 2.23 to 2.54, with an average of about 2.40.[1]

The importance of density lies in its influence on the refractoriness. The denser the clay the greater the refractoriness, other things being equal. The tests on the Missouri clays showed that "for every increase of 0.20 to 0.25 in the density of a clay, the fluxing impurities may be increased 0.5 to 1.5 without lowering the refractoriness; and, as clays are liable to range from 1.50 to 2.50 in specific gravity, it is impossible to weigh correctly the evidence of chemical analysis of a clay unless the density and fineness of grain are also given."[2] The influence of density is simply due to the fact that the greater the density, the less is the pore space, and the more difficult is the permeation of the heat. The amount of pressure used in molding bricks should have some influence on the density and fusibility. Bricks molded by the heavy machines would naturally stand more heat than bricks of the same clay molded by the lighter machines.

Fineness of Grain. — Fineness of grain is of considerable importance, though it is not yet fully understood. In clays of the same composition, the finer the grain, the more fusible the clay, as there is a greater surface to receive the heat. For this reason, manufacturers of refractory material take care not to grind their clay too fine. Plasticity, to a certain extent, depends on fineness of grain, but is influenced more by the shape than the size of the grains. Shrinkage was formerly supposed to increase with fineness of grain, but the relation is not uniform, as shrinkage is influenced by other properties as well.[3] Fineness of grain may be estimated by the feel, or by microscopic study, but most readily by the rapidity of slaking.

1 Missouri Geol. Surv., Vol. XI, 1896, p. 91.
2 Loc. cit., p. 91.

Slaking. — Slaking is the property of air-dried clay to fall to a powder when placed in water. It serves readily to detect the fineness of grain, and is also of value in the washing of clays, for, after slaking and stirring, the coarse grains separate and settle rapidly, while the fine material is decanted or siphoned off and allowed to settle.

Strength. — The strength of a clay is closely related to its plasticity. A "strong" or "fat" clay is one that is plastic and can be molded without cracking. This strength is due to the mechanically included water and to the interlocking character of the particles, which, in "strong" clays, occur as thin plates which overlap and slide over one another. On this property depend the tensile and crushing strengths. When clays have been molded and dried, they require a force varying from 20 pounds in lean clays to 300 and 400 pounds in very plastic to pull them apart. This test of tensile strength is an elaborate and accurate way of determining plasticity, but is not of much practical value, as plasticity can readily be estimated by the feel. A burned brick increases in crushing strength with the thoroughness of burning, and completely vitrified bricks have a crushing strength nearly, if not quite, equal to many granites.

Plasticity. — Plasticity is one of the most important properties of clay; still its cause has not yet been determined to full satisfaction. Plasticity has been attributed to various constituents, as the clay base, the impurities, the alumina, the included and combined water, and the platy structure of grains, but no single property can fully account for it. The impurities and the alumina have no direct connection with plasticity. Some impure clays are very plastic; others are not. The same is true of clays high in alumina. The included and combined water, as well as the platy structure, are all directly connected with the plasticity; and, with one of the three missing, plasticity is also absent.

Some clays are plastic when first mined; others require grinding to give them plasticity. When the latter are examined under the microscope, they are seen to consist, not of a compact, amorphous mass, but of bundles of small six-sided plates or scales. These bundles are broken up by grinding,

leaving the separated plates to interlock with one another and form a plastic mass. By long continued grinding the plates are destroyed, and plasticity is largely lost. Wheeler in his tests on the Missouri clays[1] concluded that clays were most plastic when their grains could be passed through sieves ranging between 50 and 100 meshes to the inch; but in the Connecticut brick clays, which are very highly plastic, over 90 per cent. of the material can, after slaking but without any grinding, be passed through a 160 mesh sieve. This fact seems to show that the platy structure can exist naturally in very small particles.

When a lump of plastic clay has dried in the air, it loses its plasticity, but regains it on addition of a sufficient amount of water. The mechanically included water acts as a lubricant, and allows the plates to slide over one another, but still holds them by capillary attraction. Too little water does not render a clay plastic, and too much causes it to slake. The proper amount can be found only by experiment. The finer and more thinly lamellar the clay, the greater is the amount of water required to produce plasticity. Some clays require over 30 per cent. water.

In fine impure clays, grains of quartz and other minerals often make up the greater part of the material; yet there is enough clay base present to give sufficient plasticity. Some clays, such as the Connecticut brick clays, consisting from two-thirds to three-quarters of sand and rock flour, are so plastic that they still require an addition of coarse, sharp sand, before they are stiff enough to hold their shape when molded.

Chemically combined water is the third constituent that has a direct bearing on plasticity. When clay is heated to red heat, this water is expelled, and the plasticity is destroyed for good. Such is naturally the case, as the platy structure belongs to the mineral kaolin, which contains 14 per cent. combined water. When this water is expelled, the mineral, and consequently the platy structure, are destroyed, and the remaining compound has no more plasticity than has any powder when mixed with water.

Other minerals, as micas, chlorite, and gypsum, are hy-

[1] Loc. cit., p. 105.

drous, have platy structure, and when ground possess some plasticity; but none possesses it in so marked a degree as kaolin. Even quartz flour has been found to be slightly plastic when wet; but, like the above minerals, lacks cohesive strength, and can stand but little handling when dried. Clay, even when dried in air for months, possesses from 1 to 2 per cent. of mechanically included water. Clay has a marked affinity for water, and readily absorbs it from a damp atmosphere, retaining it, while other substances lose it. This property, together with the platy structure, seems to account for the plasticity: the included water acts as a lubricant, while the attraction of water around the plates serves to hold them together.

Plasticity is especially important in determining the use of a clay. Plastic clay can be molded into any shape desired, as fancy pottery and china, and will retain its shape while drying. If clays are too plastic, they can be partially dried, or mixed, in lower grades of work, with a proper amount of "grog" (sand, burned clay, etc.) to diminish their plasticity to the desired degree.

Odor and Taste. — The odor and taste of clays depend upon their constituents that are volatile or soluble in water. The common argillaceous odor is readily noticed, especially in damp, plastic clay. It is due to volatile matter, perhaps largely to ammonia, all of which is driven off in heating, and the burned clay has no characteristic odor. Odor, then, only serves to confirm the presence of clayey matter in raw material. The taste of a clay is of considerable importance, as it serves to detect soluble salts that would cause efflorescence.

Shrinkage. — Shrinkage in clay is due to two causes: the expulsion of mechanically included water by air-drying, and of chemically combined water by burning. The more plastic clays suffer the most air shrinkage, as they have the most water to lose. The average amount of shrinkage has been estimated at one-twelfth the volume. Shrinkage in very plastic clays is often uneven, as the wind and sun quickly remove moisture from the exposed surfaces, while the interior of the clay does not allow its water to escape fast enough to supply the surfaces. Thus the surface shrinks rapidly, dries, and may fall away, exposing a new, moist surface. This fact is of great

importance in drying molded clay. Lean, or diluted clays, such as are used for common brick, can be dried rapidly, as their impurities and admixture of grog render them sufficiently porous to give up their water uniformly; but rich clays, used for higher grades of work, must be dried slowly and carefully to prevent cracking.

Shrinkage during burning is due partly to the driving off of what included water still remains in the clay, and partly to the expulsion of the combined water. The included water passes off at the temperature of the boiling point of water, the combined water at red heat. With the expulsion of combined water the clay shrinks to a compact, impervious mass. As was stated in the last chapter (page 37), the heat must be raised very slowly while the waters are escaping, for too rapid heating will entrap some of the water within the clay, which will turn to steam and swell or burst the brick. Large quantities of brick may be spoiled by too rapid heating. The importance of shrinkage is its influence on the size of the molds. They must be of such size that the molded clay, when burned, will have the proper size.

Color. — The color of a clay before burning is of no importance except as an indication of what the color of the burned clay will be. The presence of organic matter may obscure the true color. The color of a burned clay is important in determining the uses to which the clay may be put. The causes of the different colors have been explained under iron and lime, and it is sufficient here merely to state the colors and their causes in the following table:

COLOR OF CLAY.	CAUSE OF COLOR.
A. Before Burning.	
Gray to blue and black	Ferrous iron or organic matter.
Yellow, brown, reddish	Ferric iron in hydrated form.
White	Absence of iron and organic matter.
White efflorescence	Salts soluble in water.
B. After Burning.	
Pale salmon	Small amount of iron, or underburning.
Dark red	Over 5 per cent. of iron, and thorough burning.

Black	Ferrous iron reduced in fusion of clay by smoky flame or insufficient supply of air. Dust and fine cinders that have stuck to surface of clay while hot.
Cream to buff..................	Little iron present, or excess of lime and magnesia over iron ($CaO+MgO:FeO::3:1$).
White	Absence of iron.
White efflorescence...............	Soluble salts unexpelled.

Fusibility. — The causes of fusibility have already been treated under several different headings. To sum up, fusibility is increased (1) by the presence of fluxing impurities, as alkalies, iron, lime, and magnesia; (2) by diminution of density; and (3) by increase in fineness of grain. The following paragraph, quoted from the report on the Missouri clays,[1] will give a good general idea of the process of fusion:

"On heating a clay beyond red heat, it is found to become harder, to shrink, and to become closer-grained as the temperature is increased. On heating it still farther a point is reached when it becomes very hard, attaining a hardness of 6.0 to 6.5 (easily scratching glass); it has almost completed shrinkage, it has become very strong, and the individual grains can no longer be recognized. This point is called the point of incipient vitrification (fusion). While the clay lacks all signs of fusion and is stiff and rigid at this temperature, it shows sufficient flow or movement of the particles towards one another to obliterate individual grains, and thereby attains greater density, as it has a decided resemblance to being vitrified. On heating the clay from 100° to 300° F. above this point of incipient vitrification, the density is still further increased by a further and final shrinkage; the hardness becomes somewhat greater, or from 6.5 to 7, while the grains are not only completely obliterated, but the fracture is now like that of china or vitrified ware. This point is called the point of complete vitrification, and the clay, still stiff, retains its form and shape, though it shows greater movement among its particles. On heating the clay from 100° to 400° F. higher, the clay begins to warp and sag, slightly at first, but more readily as the heat

1 Loc. cit., p. 130.

is increased, and to swell and blister; while, on breaking, it is found to be more or less vesicular and scoriaceous. This point is called the point of viscous or scoriaceous vitrification, as the particles are sufficiently fluid that chemical reactions begin which give rise to the gas bubbles that cause the clay to swell and give it the vesicular structure; and, although it is too stiff and pasty to become decidedly liquid, it has attained a temperature when it would fail in all the practical applications of a clay."

The fusibility of a clay may be determined by physical or chemical means. The physical methods consist of fusion in a furnace and finding the temperature by means of a pyrometer. There are several kinds of pyrometers, but the kind mostly used in clay determinations is the series of Seger cones. These cones consist of mixtures of kaolin and fluxes, which are mixed in definite proportions and have definite fusing points, 36° F. apart. The temperature of fusion of the clay is the same as that of the cone the top of which has bent over to the floor at the time the clay fuses. Where very accurate work is desired, these cones are unsatisfactory, as the temperature may still be rising while they are bending over; but their determinations of the fusing points of clays are sufficiently close for all practical purposes.

The chemical method is the calculation by formula from the chemical analysis. Several attempts have been made to deduce such a formula, and all are only approximate. Perhaps the most accurate is that of Wheeler,[1] given below, which is intended to express the "fusibility factor," or a numerical value for the relative refractoriness of a clay. The higher the value, the more refractory the clay.

"
$$F\,F = \frac{N}{D + D^1} \qquad (A)$$

when the clays have the same specific gravity and fineness of grain. In this formula F F represents the numerical value of the refractoriness. N represents the sum of the non-detrimental constituents, or total silica, alumina, water, moisture, and carbonic acid (carbon dioxide). D represents the sum of

1 Missouri Geol. Surv., Vol. XI, 1896, pp. 149, 150.

the fluxing impurities, or the alkalies, oxides of iron, lime, and magnesia. D^1 represents the sum of the alkalies, which are estimated to have double the fluxing value of the other detrimentals, and are hence added twice."

"When the clays to be compared differ in density and fineness, it is necessary to modify formula A by a constant C that will have different values depending on the density and fineness, so that the formula will be

$$FF = \frac{N}{D + D^1 + C} \qquad (B)$$

in which N, D, and D^1 have the same value as in (A).

C = 1, when clay is coarse-grained and specific gravity exceeds 2.25.

C = 2, when clay is coarse-grained and specific gravity ranges from 2.00 to 2.25.

C = 3, when clay is coarse-grained and specific gravity ranges from 1.75 to 2.00.

C = 2, when clay is fine-grained and specific gravity exceeds 2.25.

C = 3, when clay is fine-grained and specific gravity ranges from 2.00 to 2.25.

C = 4, when clay is fine-grained and specific gravity ranges from 1.75 to 2.00.

These values of C are only approximate, but are near enough to make comparisons."

The following are a few values taken from Wheeler's tables,[1] and will serve as a comparison with the calculated fusibilities of some of the Connecticut clays:

No. of Sample		SiO_2	Al_2O_3	H_2O	Total N	D^1 Alk.	Total D	Sp. Grav.	Grain	Fusibility			Value of FF from	
										Incipient	Complete	Scoriaceous	A	B
										°F				
Flint clays	7	67.47	19.33	7.73	94.53	1.07	5.14	2.44	very coarse	2250°	2450°	2700°	15.2	13.3
	4	53.90	28.85	11.61	94.36	0.85	6.86	2.40	coarse	2200	2400	2600	12.2	10.9
Kaolin	17	72.30	18.94	7.04	98.28	0.42	1.89	1.89	very fine	2200	2400	2600	42.5	15.6
Potter's clay	25	74.02	15.26	3.69	92.97	2.37	5.38	2.37	fine	2100	2300	2500	12.0	10.6
	24	67.76	21.96	8.23	97.95	0.24	2.43	2.45	coarse	2500	2700	2700	46.0	27.0
Brick clays (Loess)	26	72.00	11.97	6.42	90.19	3.25	10.11	2.17	fine	2000	2200	2300	6.8	5.7
	28	73.92	11.65	5.26	90.83	3.13	9.90	1.98	fine	1800	2000	2100	6.8	5.3
Shales	30	54.80	23.73	6.00	84.53	3.80	15.34	2.37	very fine	1500	1700	1900	4.4	4.0
	32	57.01	24.43	7.63	89.07	3.81	11.47	2.39	coarse	1600	1800	2000	5.8	5.5

1 Loc. cit., pp. 150, 151.

CHAPTER VI.

Commercial Classification of Clays.

It is obvious, after a consideration of the various properties of clay, that a strictly geological classification, such as that given in the early part of this bulletin, is of little or no value, save to the geologist or prospector. A classification for the clay-worker should be based upon the composition and properties of the clay, for on them depends the adaptability of the clay for the various uses. As variations in clays are almost unlimited, such a classification can only be general, and the names given to the different types are usually taken from the most important products made from the clay. Thus we have *china clay, pipe clay, brick clay,* etc. Such names, though corresponding to no scientific classification, convey a definite idea to the clay-worker; but some of them, for example, *brick clay,* are general names, and require subdivision, as *fire-brick, yellow brick, paving brick, and common brick,* every name now giving a definite idea of the properties of the clay. Clays have been generally classified as: (1) kaolins, china clays, and ball clays; (2) fire-clays; (3) glass-pot clays; (4) stoneware clays; (5) clays for vitrified wares; (6) terra cotta clays; (7) brick clays of different kinds; and (8) slip clays.

(1) *Kaolins, China, and Ball Clays.* — Kaolins, china, and ball clays are used in the manufacture of porcelain, china, and white earthenware. Their requisite properties are fine grain, homogeneity, plasticity, freedom from iron and fluxing impurities. Most clays of this class require washing or grinding before they are suitable for use, and feldspar and quartz are usually added to make a compound with all the desired properties. The feldspar, fusing before the clay, cements the particles and furnishes the white glaze. These clays should fuse at about 2,350° F.[1]

[1] H. Ries, Clays of U. S. East of Miss. R., Prof. Paper No. 11. U. S. G. S., 1903, p. 37.

The analyses of washed kaolins show the following range of constituents:[1]

	Maximum.	Minimum.	Average of 8 analyses.
SiO_2	59.42	45.70	48.98
Al_2O_3	40.61	27.15	35.89
Fe_2O_3	1.77	0.46	0.97
CaO	0.45	Trace to 0.00	0.23
MgO	2.42	Trace to 0.00	0.47
Na_2O+K_2O	2.82	1.10	1.67
H_2O	13.54	8.95	11.42

Clay used in the manufacture of paper must have natural white color and be free from grit. Its other properties are unimportant. Kaolin is the principal type of clay used.

(2) *Fire-Clays.* — The chief requirements of fire-clays are the withstanding of very high temperatures, 2,500° to 2,700° F., and a moderate amount of plasticity. Coarse grain and high specific gravity are important properties. Mixtures of clay are necessary for the best results. Analyses show the following ranges:[2]

	Maximum.	Minimum.	Average of 9 analyses.
SiO_2	74.25	44.20	56.69
Al_2O_3	38.66	17.25	28.40
FeO	1.93	0.46	1.11
Fe_2O_3	2.51	0.74	1.30
CaO	0.50	Trace	0.30
MgO	0.89	Trace	0.36
Na_2O+K_2O	2.69	0.44	1.21
TiO_2	1.78	1.10	1.37
H_2O	13.55	6.30	9.94

(3) *Glass-Pot Clays.* — Clays for the manufacture of glass-pots must be refractory, burn dense, resisting the fluxing action of glass, possess good bonding power, and burn without warping. Very few clays in the United States are suitable for this use, and those used are mixed with an imported German clay.

(4) *Stoneware Clays.* — Stoneware clay is a semi-refractory clay, which molds easily, and holds its shape while burning. It should be fairly free from iron, but should contain

1 Values taken and computed from Prof. Paper 11, U. S. G. S., p. 39.

2 Compiled from Prof. Paper 11, U. S. G. S.

enough fluxing impurities to cause incipient fusion at fairly high temperatures and produce a non-porous ware. Chemical analyses range as follows:[1]

	Maximum.	Minimum.	Average of 8 analyses.
SiO_2	72.10	45.00	64.08
Al_2O_3	38.24	19.08	23.86
Fe_2O_3	1.50	0.96	1.23
CaO	1.70	0.00	0.78
MgO	0.68	0.11	0.40
Na_2O	Trace	0.00	Trace
K_2O	2.42	0.15	1.48
Li_2O (with Na_2O)	0.02	Trace to 0.00	Trace
TiO_2	1.30	0.29	0.46
H_2O	14.80	6.25	7.78

(5) *Clays for Vitrified Wares.* — This class includes such clays as are used for sewer pipe, paving brick, etc., which do not have to withstand high temperatures. Clays of this class should be fine-grained and plastic, and should vitrify at a low temperature, 2,130° to 2,210° F. They should, therefore, be high in fluxing impurities, especially iron and alkalies, but should be fairly low in lime and magnesia, as their presence in great amount would tend to bring the points of incipient and complete fusion too close together. These two points should be 150° to 200° F. apart. The following table of analyses is taken from the Report on the Missouri clays:

	Maximum.	Minimum.	Average.
SiO_2	75.00	49.00	56.00
Al_2O_3	25.00	11.00	20.50
Fe_2O_3	9.00	2.00	6.70
CaO	3.50	0.20	1.20
MgO	3.00	0.10	1.40
Na_2O+K_2O	5.50	1.00	3.70
Loss on ignition	13.00	3.00	7.00

In all three of the above columns, the ratio of iron plus alkalies to lime plus magnesia is over 2:1.

(6) *Terra Cotta Clays.* — Terra cotta and bricks can be made from clays of so widely different character that an average analysis would be meaningless. The greater part of terra

[1] Table compiled from analyses in G. P. Merrill's "Nonmetallic Minerals," Rep. of Nat'l Mus., 1899.

cotta is now made from a mixture of fire-clays, which burn to a buff color at from 2,280° to 2,350° F. The surface color is made by a slip or glaze.[1] Low grade terra cotta is also made from red-burning clays.

(7) *Brick Clays.* — Fire-brick and paving-brick clays have already been mentioned. Other clays serve for making (*a*) yellow and buff building brick, (*b*) common red brick and earthenware, and (*c*) pressed brick.

(*a*) The yellow and buff brick are made from plastic clays high in lime and magnesia, and comparatively low in iron. The clay should not be too easily fused, as the brick is then in danger of warping. Consequently bricks of this type are likely to be comparatively porous and weak.

(*b*) Common red-burning brick clays should contain at least 5 per cent. iron oxides, and preferably not over 8 per cent., as a greater amount simply lowers the fusing point without improving the color. Red-burning clays burn to a dense body at low temperatures, and fuse slowly enough to give, with sufficient care, a hard body of little porosity without sagging. Most brick clays have a large percentage of fluxes, and commonly show incipient fusion at a little over 1,900° F., and should burn hard at a temperature not over 2,000° F.[2] Clays are often too plastic to retain their shape alone when molded, and are diluted with lean or burned clay, or, preferably, sharp sand that is not too coarse.

The percentages of constituents in classes (*a*) and (*b*) are as follows:[3]

	Maximum.	Minimum.	Average.
SiO_2	90.877	34.35	49.27
Al_2O_3	34.00	22.14	22.77
Fe_2O_3	15.00	0.126	5.31
CaO	13.20	0.024	2.017
MgO	11.03	0.02	2.66
Na_2O+K_2O	15.32	0.17	2.768
H_2O (combined)	13.60	0.05	5.749
H_2O (mechanically included)	9.64	0.17	2.505

1 Prof. Paper No. 11, U. S. G. S., p. 43.

2 Ibid., p. 45.

3 Ibid., p. 45.

Earthenware is made from the finer and less gritty brick clays. Plasticity, easy molding, and burning to a porous body without too great shrinkage are the essential properties.

(*c*) Pressed brick is at present mostly made from more or less refractory clays, as the light color produced is popular, and makes a good base with which artificial coloring material may be mixed. Red clays make good enough brick, but the color is at present out of fashion. The requirements for a pressed-brick clay are uniformity of color when burned, and fairly low shrinkage to preserve straightness of outline. Refractoriness and plasticity are not important, though excessive plasticity is undesirable where the stiff-mud process is employed.[1] Typical analyses are similar to those given for common brick.

(8) *Slip Clays.* — Slip clays are clays fusing at a low temperature to a fluid, so that they can be used as a glaze on stone- and chemical ware. Their requirements are exceedingly fine grain, very high percentage of fluxes, and a fairly rapid fusion to a liquid so that they will form a smooth glaze. High percentage of lime and magnesia, especially in form of carbonates, and comparatively low amounts of iron oxides would probably cause this last property. The chemical analysis of the slip clay from Albany, N. Y., is as follows:[2]

SiO_2	58.54
Al_2O_3	15.41
Fe_2O_3	3.19
CaO	6.30
MgO	3.40
Na_2O+K_2O	4.45
Sulphuric acid	1.10
Carbonic acid and water	8.08
Total	100.47

(9) *Other Clays.* — Loess is a fine material, occurring in the Mississippi valley, intermediate between a sand and clay, and is sometimes used for brick-making. Adobe is an impure

1 Prof. Paper 11, p. 44.
2 G. P. Merrill, Rep. of U. S. Nat'l Mus., 1899, p. 335.

clay, largely transported by wind, that occurs in the arid valleys of the southwest. It is mixed with straw and dried, and can be used in that dry climate without burning for building purposes. Fuller's earth is a very fine clay, used, on account of its absorbent nature, to remove grease from clothing. Its other properties are not essential.

CHAPTER VII.

Composition, Properties, and Adaptability of the Connecticut Clays.

There are in Connecticut four kinds of clay deposits: — residual kaolin, Glacial till, red shale, and the lacustrine or estuarine clays of post-Glacial origin. Only the first and last-named of these deposits are of commercial value. The till and shale could probably, by screening and grinding, make good brick; but they would even then not be any better than the post-Glacial clays derived from them, while the cost and labor necessary for preparing them prevents their use. The prepared material would be similar to the post-Glacial clays in composition and properties, and so need not be considered separately.

COMPOSITION AND PROPERTIES OF KAOLIN FROM WEST CORNWALL.

As the West Cornwall kaolin is the residual product of a feldspathic quartzite, it naturally contains a large amount of free silica, or quartz, with small amounts of fluxing impurities which originally existed in the feldspars. The chemical analysis of the washed material, made for the Kaolin Company of West Cornwall, is as follows: —

Silica	47.50
Alumina	37.40
Iron oxide	0.80
Lime	Trace
Magnesia	0.00
Alkalies	1.10
Water	12.48
Total	99.28

This analysis places the clay among the first-grade kaolins of the country. The low percentage of iron permits the pro-

duction of a white body, while the sum of all the fluxes is insignificant. The free silica is almost removed by washing, and the rational analysis shows

Clay substance	99.00
Quartz	1.00
Total	100.00

The washed clay is very white, is rather granular to the feel, and apparently lacks plasticity; but several experiments and practical tests have shown that, when mixed in a body, the mixture is equal in plasticity to that of bodies made from other kaolins. The material is also highly refractory, as its analysis indicates. Its fusing point is somewhat higher than 3,000° F.

The burned clay is very white, and begins to show a mere tinge of yellow, due to the small amount of iron present, when heated to a high temperature such as would be required for the manufacture of china. This iron is associated in most cases either with tiny scales of mica or small quartz grains, which can only be eliminated with considerable difficulty. These qualities adapt the kaolin for use in sanitary ware, wall tile, semi-porcelain china, and wares of similar grade.

COMPOSITION AND PROPERTIES OF THE LACUSTRINE AND ESTUARINE CLAYS.

Both physical and chemical tests show that the different deposits of central Connecticut are all very similar both in composition and properties. They will, therefore, be treated as a group, while separate mention will be made where one clay differs to a noteworthy degree from the others.

COMPOSITION.

A glance at the following analyses of typical samples will show that the clays are very impure. These analyses were made in the laboratory of the United States Geological Survey by Mr. W. T. Schaller under the direction of Dr. F. W. Clarke, chief chemist.

Number	1	2	3	4[1]	5[1]
Silica, SiO_2	52.73	50.33	55.27	58.02	56.75
Alumina,[2] Al_2O_3	22.25	27.06	20.52	17.93	17.54
Ferric oxide, Fe_2O_3	3.14	2.29	5.34	4.89	4.92
Ferrous oxide, FeO	4.55	2.62	1.55	1.24	0.93
Lime, CaO	1.48	1.22	2.21	3.42	4.18
Magnesia, MgO	3.20	3.34	2.80	1.92	2.34
Soda, Na_2O	2.22	1.78	2.82	3.33	3.40
Potash, K_2O	4.28	4.40	3.43	3.06	3.16
Water (loss) at 107° C.	1.12	1.42	1.37	0.99	1.24
Water (loss) on ignition[3]	4.91	5.24	5.06	5.36	6.28
Total	99.88	99.70	100.37	100.16	100.74

[1] Clay tempered with sand.
[2] Alumina includes possible titanium dioxide and phosphorus pentoxide.
[3] Includes carbon dioxide, and possible chlorine and sulphur dioxide.

No. 1, from East Windsor Hill Brick Co., South Windsor, Conn.
No. 2, from Park Brick Co., West Hartford (Elmwood), Conn.
No. 3, from Tuttle Brothers, Newfield, Conn.
No. 4, from Berlin Brick Co., Berlin, Conn.
No. 5, from I. L. Stiles & Son, North Haven, Conn.

Clay Base. — The amount of clay base present can only be approximately estimated, as examination under the microscope shows the presence of feldspar, chlorite, micas, and garnet, all of which contain alumina. In white mica there are three molecules of alumina to one of alkalies, but in black mica and chlorite the alumina is less than the sum of the other bases, so the total number of alumina molecules in these minerals may be considered to equal approximately the total of the other bases. The percentage of water above 107° does not furnish a basis for accurate calculation, as limonite, chlorite, the micas, and possibly some of the zeolites, all contain combined water, and the percentages shown in the analyses include carbon dioxide and probably small amounts of other volatile constituents. Ferrous oxide, magnesia, and lime, may be present both in the above-named minerals, where they replace one another, and also in the form of carbonate; but, as lime is the most likely to occur as carbonate, and the least likely to remain in altered ferro-magnesian minerals, it was dropped from the calculation, the small amount of lime in the silicates roughly

compensating for the other bases in the carbonates. The calculation, therefore, is made on the assumption that every molecule of ferrous oxide, magnesia, and alkalies is combined with a molecule of alumina, while the remainder of the alumina is estimated in the clay base with proportionate amounts of silica and combined water. The results obtained for the clay base, as is shown by the amount of combined water required, are all a little too high, probably because too great a percentage of bases was allowed for carbonates.

		1	2	3	4[1]	5[1]
Clay base	SiO_2	15.88	21.96	15.83	13.23	12.94
	Al_2O_3	13.49	18.76	13.45	11.46	10.99
	H_2O	4.78	6.64	4.76	4.06	3.89
Total clay base		34.15	47.36	34.04	28.75	27.82
Non-fluxing impurities	SiO_2	36.85	28.37	39.44	44.79	43.81
	Al_2O_3	8.76	8.30	7.07	6.47	6.55
	H_2O	1.25	0.02	1.67	2.29	3.63
Total non-flux. impurities		46.86	36.69	48.18	53.55	53.99
Fluxing impurities	Fe_2O_3	3.14	2.29	5.34	4.89	4.92
	FeO	4.55	2.62	1.55	1.24	0.93
	CaO	1.48	1.22	2.21	3.42	4.18
	MgO	3.20	3.34	2.80	1.92	2.24
	Na_2O	2.22	1.78	2.82	3.33	3.40
	K_2O	4.28	4.40	3.43	3.06	3.16
Total fluxes		18.87	15.65	18.15	17.86	18.93
Sum total		99.88	99.70	100.37	100.16	100.74

[1] Clay tempered with sand.

The clay base comprises from about one-fifth in tempered clay to over one-third the whole mass in the unmixed clay, while the greater part is sand and rock flour, which the microscope shows to consist mostly of quartz, with smaller quantities of mica, feldspar, chlorite, and occasionally garnet, all

but quartz containing fluxing impurities. The quartz serves simply as a natural grog for the clay base, while the use of the clay is dependent upon the fluxing impurities.

Iron Oxides. — The iron oxides are present in all the samples, ranging from a little below 5 to over 7.5 per cent. The ferrous oxide predominates in No. 1, a blue clay; the two oxides are nearly equal in No. 2, which has a grayish brown color; while in the other samples, all of brown clay, the ferric oxide is greatly in excess of the ferrous. When it is remembered that clay containing less than 5 per cent. iron oxides burns to a distinct but not deep red, it is evident that the Connecticut clays can only be used where a red color is desirable. Most of the clays contain sufficient iron to give a deep red when thoroughly burned; but sample No. 2, with slightly less than 5 per cent., contains hardly enough to give a deep red. This defect could be remedied by mixing hematite, or red oxide of iron, with the clay when tempering it. One pound of hematite to 100 pounds of clay would improve the color, while two pounds would insure a deep red, increasing the percentage of iron oxides to 6.75 per cent. The hematite should be thoroughly mixed with the clay. Some brick-makers use hematite in molding. The bricks thus get a good color on the surface but it often becomes worn off with much handling, revealing the true pale color of the brick. This addition of hematite would increase the percentage of fluxing impurities, but the total impurities even then would be slightly less than in the other samples; so the quality of the clay would not be impaired for brick-making.

Lime and Magnesia. — The lime and magnesia are also rather high, ranging from 4.5 to over 5 per cent. They are, in all probability, partly present as carbonates, and it is possible that in samples 2 and 5, where they are nearly equal in amount to the iron oxides, they diminish somewhat the coloring effect of the iron. Addition of hematite would also overcome this effect on the color; but, in the case of sample 5, might make the total amount of fluxes higher than is desirable.

Alkalies. — The alkalies are always very high, over 6 per

cent., and their combined effect is greatly to reduce the fusing point. Their high percentage indicates a considerable amount of feldspar grains, which fuse quietly and slowly, so that the fusing clay may become viscous, but not sufficiently liquid to form a good slip clay.

PHYSICAL PROPERTIES.

Structure. — The lacustrine clays are nearly all banded, layers of strong clay alternating with layers of very fine quicksand. At a few clay banks, however, notably those near the edges of the Berlin area, some along the edge of the Quinnipiac, and that at Milldale, the clays are not distinctly banded, but are of fine, sandy quality throughout. They are more thoroughly tempered by nature, often making addition of tempering sand unnecessary.

At several places, especially at Berlin and Quinnipiac, the clay is divided by vertical joints into roughly hexagonal blocks, thus facilitating undermining. The soft nature of the clay permits plowing, which is employed at a few yards where the clay in the bank is too moist for working and has to be partly dried before molding. The horizontal character of the beds adapts them especially to working by benches, especially in the deeper pits.

Hardness. — The clays as a whole are all soft and easily worked; but their highly quartzose character gives them some wearing effect on the machine, varying with the stiffness of the clay.

Feel. — Most of the ten samples tested had an extremely soft, greasy feel when rubbed between the fingers, and showed only very fine grit when ground between the teeth. The samples from Berlin (American Brick Co.) and from Milldale (Clark Bros.) showed considerable grit when rubbed between the fingers, and were comparatively very gritty to the teeth; but even they would be classed as having a greasy feel.

Homogeneity. — The clays in general are not homogeneous, but possess a distinct banded structure. The alternation of layers, however, is very uniform, so that the clay after passing

through the pug mill is sufficiently homogenous for all its possible uses, except where, through carelessness or accident, pebbles are allowed to remain in the clay. If the clays are slaked, then shaken up in water, and allowed to settle for two or three days, a thin layer will settle over the bottom of the vessel, while by far the greater part remains in suspension for several days.

Fineness of Grain. — The clays are all very fine, as the following rapid test shows. Of a quantity put through a 160-mesh sieve, less than 0.5 per cent. of any sample was caught on the sieve, while the greater part passed through a 200-mesh sieve. Such extreme fineness of grain accounts largely for the high plasticity, indicates considerable degree of shrinkage, and serves also to lower the fusing point.

Density. — The high percentage of free silica, feldspar, and iron oxides indicates a fairly high specific gravity, which is somewhat diminished by the fine grain.

Slaking. — As would be expected with such fine-grained clays, all the samples slaked very rapidly. Five minutes was generally sufficient for the slaking to be completed.

Strength. — Merely feeling the clays shows that they are all strong, although the clays above mentioned as occurring near the margins of deposits are comparatively lean. The tensile strength test was not considered necessary for such plastic clays, as the simple feel is sufficient for practical purposes.

Plasticity. — The high plasticity of the clays has already been mentioned. The clays, in most cases, are mined below ground-water level, and contain enough water to make them highly plastic, so that they can be conveyed directly to the machine and tempered without addition of more water. The plasticity is evidently due to the fine grain, the impurities being so fine as not to diminish, and possibly to increase, the plasticity when wet, and the clay base being in sufficient amount to give the desired cohesive strength to the dried material, even when tempered with 30 per cent. of sharp sand.

Odor and Taste. — The argillaceous odor was strong in all the clays. All of the ten samples were tasteless, thus indicating the absence of an appreciable amount of soluble salts; but

the strong argillaceous odor might easily have obscured small amounts of soluble salts. An unpublished analysis, made in the geological department of the Massachusetts Institute of Technology, of a sample from the Quinnipiac clay showed less than 0.1 per cent. of total soluble salts. Flood tides sometimes reach into the Quinnipiac clay pits, and, on evaporation, leave a white coating of salt over the surface. This would add slightly to the fusibility, but would probably cause no efflorescence on the burning clay.

Shrinkage. — As the means for a fire test were not available, no tests on shrinkage were made, since a test on air shrinkage alone would be of no value. It is, however, evident from the fine grain and high degree of plasticity that the total shrinkage is considerable.

Color. — The color of the clays, both before and after burning, needs no further explanation. It is always due to iron, but the red color may be, as shown in analyses 2 and 5, slightly diminished by the effect of the lime and magnesia.

Fusibility. — As was the case with shrinkage, the means at hand were not sufficient to allow physical tests in the furnace; but the approximate fusing points may be calculated from the analyses by Wheeler's formula (A), given on page 49. The fineness of grain and high percentages of fluxes show immediately that the fusing points will be very low. The results of the calculations are as follows: —

No.	SiO_2	Al_2O_3	H_2O	Total N	Alk. D[1]	Total D	Grain	Fusibility Factor
1	52.73	22.25	6.03	81.01	6.50	18.87	Very fine	3.19
2	50.33	27.06	6.66	84.05	6.18	15.65	Very fine	3.85
3	58.02	17.93	6.35	82.30	6.39	17.86	Very fine	3.39
4	55.27	20.52	6.43	82.22	6.25	18.15	Very fine	3.37
5	56.75	17.54	7.52	81.81	6.56	18.93	Very fine	3.34

Comparison with the values selected from the Missouri clays, page 50, shows that the Connecticut brick clays are distinctly more fusible than the lowest value given. That is, they begin to fuse considerably below 1,500° F., and attain complete vitrification considerably below 1,700° F. This remarkably

low fusing point does not detract from their value as brick clays, but is an advantage in that less fuel is necessary than with other clays to produce well burned bricks.

ADAPTABILITY OF THE CENTRAL CONNECTICUT CLAYS FOR VARIOUS USES.

The high percentage of iron and the extremely low fusing points of the clays limit them to uses where red color is desired and refractoriness is unnecessary, i. e., red earthenware, common and hollow brick, and probably paving, or vitrified, and pressed brick. The fusing point is too low to allow their use for red terra cotta, which is generally expected to withstand fairly high temperatures. Drain tile can be, and has been, manufactured from these clays. Their low fusibility suggests that they might make good slip clays, but experiment has proved the contrary, as they fuse too slowly, and give a rough instead of a smooth coating. Comparison of the analyses of the Connecticut clays with that of the Albany slip clay, page 55, shows the Albany clay to contain large amounts of lime and magnesia, largely as carbonates, with comparatively low iron. This is not the case with the Connecticut clays, and the cause seems to lie in the ability of the high lime and magnesia to produce a more liquid fusion, while the more silicious and ferruginous clays become more viscous than liquid. This statement, however, has not been proved.

The clays are adapted to the best quality of common brick at low expense, if handled with a fair amount of care and skill. The percentage of shrinkage is perhaps too great to give the best results for pressed brick; but, if partially air-dried before molding, they should suffice. The chief difficulty with their use for pressed brick is their red color when burned, which is at present unpopular. Their low fusing points favor their use for vitrified wares of low grade, as paving brick and sewer pipe. Their points of incipient and complete vitrification should be, and probably are, sufficiently far apart (150° to 200° F.) to warrant their use; but actual tests of fire, crushing, and abrasion are necessary to prove their adaptability. A possible objection to their use as paving brick would be that

their too complete fusion and extremely fine grain would produce a smooth and slippery surface, or one that would soon wear smooth. This difficulty could probably be avoided by admixture of a sufficient amount of sand, by molding under high pressure, and by care not to raise the heat too high above the point of incipient fusion.

PART II

The Clay Industries of Connecticut

CHAPTER I.

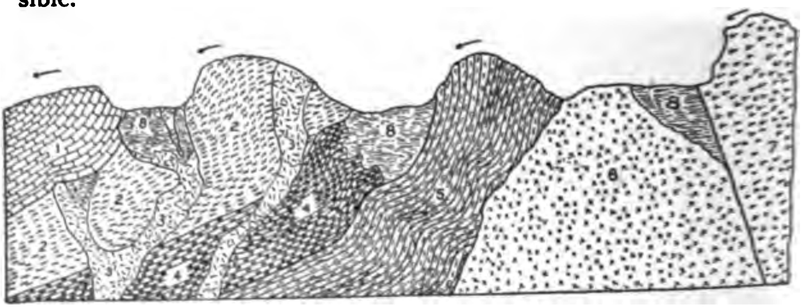
Prospecting: Mining of Kaolin.

The clay industries of Connecticut have included in past years several varieties of manufacture; but at present, besides the mining of kaolin, the only industries are the manufacture of brick, stoneware, and earthenware. These industries will be described in not too great detail, for the benefit of those unfamiliar with them. No descriptions of individual plants will be given, as all are essentially alike, and, with the information given in the following chapters, any further details can be readily seen by visiting the plant in question.

PROSPECTING.

The first and most important thing to know when entering upon any of the clay industries, is the extent and position of the clay deposit; for on these facts should depend the location of the plant. The following brief discussion is intended to give a few general facts that are essential in prospecting. In the country north of the great terminal moraine (that is, throughout New England), residual clays can only be found in valleys protected by a steep slope on the north, which protected them from glacial erosion. In New England, where the transported clays are so abundant and accessible, kaolins are the only residual clays of value. Residual clays from most igneous rocks would be too high in iron to give anything but a red color, and their location in the highlands would prevent competition with the transported clays, which are located mostly along the main lines of railroads. Kaolins of good quality can result only from rocks high in feldspar and very low in dark, iron-bearing minerals, as pegmatites, a few granitic rocks, and rarely, as at West Cornwall, feldspathic sedimentary or metamorphic rocks. Two conditions, then, are essential for finding a kaolin deposit: the country must be rugged, or mountainous, where steep-sided valleys are likely to occur, and a vein of pegmatite, or an exposure of other feld-

spathic and iron-free rock, must be found, which can be followed into one of the steep valleys, protected on the north by a steep slope of hard, resistant rock. These conditions are illustrated by the diagram on this page. When in such a valley a kaolin deposit is found, the extent, both in length, breadth, and depth, should be ascertained, and the plant so erected that the clay may be most easily obtained at as small a cost as possible.



GENERALIZED SECTION SHOWING THREE POSSIBLE OCCURRENCES OF KAOLIN IN GLACIATED COUNTRY.

1 = limestone; 2 = mica schist; 3 = pegmatite; 4 = feldspathic quartzite; 5 = dark gneiss; 6 = light granite; 7 = dark granite; 8 = kaolin, protected from glacial erosion. Arrows indicate direction of ice movement.

The location of transported clays in New England is a very simple matter. Almost any flat area of considerable size, surrounded by high land, is likely to contain a greater or less thickness of impure clay. The nature of these deposits should be borne in mind. They were all formed either in estuaries, lakes, or river floods; and at their margins, where wave action was strongest, and where the coarsest sediments were deposited, only coarse gravels are found; farther from the margin, the gravels shade rather abruptly into sands and clays, which accumulated as long as the lakes existed. The surface of the clay is often covered by a layer of sand, diminishing in thickness towards the middle of the basin, which may hide all the clay from view, except along stream banks. Plate II illustrates the relation of the clay to the other formations.

Whether the clay is covered by sand or not, a systematic series of borings should be made, to show the extent, depth, and character of the underlying clay, and the thickness of the

overlying sand. When these facts are known, it will be possible to erect the plant where the clay is either wanting or of poor quality, or is covered by too great a thickness of sand to allow profitable working. The presence of terraced streams is also a thing to be remembered, as clay pits dug into these terraces can be made self-draining. If poor judgment is used in erecting the plant, the best clay may be covered, and the plant in time will either have to be abandoned or remodeled at a considerable expense and loss of time.

Shales and pre-Glacial transported clays, owing to their folded or tilted character, generally outcrop in belts across the country. Their extent may be found by boring, and by finding their inclination to the horizontal.

MINING OF KAOLIN.

The kaolin at West Cornwall, the only deposit worked at present, is mined by the hydraulic method. A pit is excavated, and a stream of water directed against the sides, washing the material into the pit, where much of the sand settles out. The finer particles still in suspension are pumped up and floated through a thousand feet of troughing into settling tanks, where the finer sand settles. The kaolin is removed from the tanks, and dried in a rotary drier, from which it is elevated and conveyed to its respective bins.[1] Hydraulic mining is a very rapid and economical method, as large excavations can be made with only one or two men to direct the stream of water.

There are no works at the present time in the state that use kaolin, and the product mined at West Cornwall is shipped to large pottery concerns at Trenton and Camden, N. J., East Liverpool, Zanesville, and Steubenville, Ohio, Morristown, Penn., and Maywood, N. Y.

MINING OF FELDSPAR AND QUARTZ.

There is, besides kaolin, a large quantity of feldspar and quartz mined in Connecticut. In fact, Connecticut is one of the chief producers of these materials in the United States.

---

1 For a detailed description of the washing process, see Bull. New York State Museum No. 35, p. 799, or Prof. Paper No. 11, U. S. Geol. Survey.

The principal producing localities in the state are South Glastonbury and Branchville, though other places have, in times past, produced limited quantities. The "Old Silex" Mine at Lantern Hill in North Stonington has also furnished quartz. Quartz and feldspar are milled near the quarries, and shipped to companies in other states for the manufacture of china, crockery, glass, etc.

PLATE IV. TERRACE IN CLAY BEDS AT PARKVILLE

PLATE V. - DAVIS' CLAY PIT, QUINNIPIAC.

Shows method of working by benches. Left hand bench is worked out, middle and right ...

CHAPTER II.

The Manufacture of Brick.

The manufacture of brick is divided into several parts: (*a*) mining the clay, (*b*) conveying to the machine, (*c*) preparing for the machine, (*d*) grinding, (*e*) molding, and (*f*) burning.

MINING THE CLAY.

The method used in mining the clay depends largely upon the condition of the clay bank — whether deep or shallow, dry or moist. The chief methods, all of which are employed to some extent in Connecticut, are undermining, mining by benches, by plowing, and by steam shovel.

(1) *Undermining.* — Undermining is a simple, but rather dangerous method, generally used only in shallow pits, where the clay is fairly dry. The clay is dug away at the foot of the bank, and wooden wedges are driven in at the surface, two to three feet from the edge, forcing out the mass of unsupported clay, which breaks by falling.

(2) *Benches.* — Mining by benches is adapted to any clay bank, especially where the clay is moist and soft. The process consists in digging with shovels along one level as far as convenience in loading will allow, and then starting a new level about two feet below the first, and so on, until the first level is again brought within reach of convenient loading. By systematic development of these levels, the ground water can be made to collect in one corner of the pit and from there be pumped out, or, in the case of terrace pits, it can be made to flow out of the pit into the stream.

(3) *Plowing.* — Where the clay is too moist for immediate use, or where it requires weathering, the method of plowing is used. The broken lumps of plowed clay are quickly dried by the wind and sun. Only a few yards in Connecticut need to employ this method.

(4) *Steam Shovel.* — The steam shovel is capable of digging large quantities of clay rapidly, one shovelful filling an

ordinary one-horse dump cart. This method is a great saver of labor where large quantities of clay are used, and where it can be kept in continuous operation; but most yards in Connecticut are too small to use a steam shovel with economy.

CONVEYING TO THE MACHINE.

Conveying the clay to the machine is usually done by horses and carts, or small cars, occasionally by cars hauled by cable, and, in one instance, by steam locomotive and cars. The chief influence on the method of carrying is the distance. If the machine is within a few hundred feet of the bank, carts are the most convenient, as two or three carts can supply the machine, and the cost of keeping them is not high. If the machine is farther away from the bank, more carts are needed to supply enough clay, and the cost of keeping the road in repair must also be considered. In many pits the roads are not properly cared for, and deep, uneven ruts are soon worn into the clay, making hauling more difficult, and wearing out both cart and horse in a relatively short time.

In such a case, both cost and labor could be saved by building a small track and hauling in cars. One horse can haul two cars more easily than one cart, and can return to haul two more while the first two are being dumped. Thus in yards of ordinary size only one horse is necessary to supply a sufficient amount of clay.

When the height of the machine above the pit is considerable, the most economical method of hauling is by cable, hauling the cars up an inclined track. If the distance is short, the cars may be hauled by cable all the way; if too great, as in older pits, the cars may be hauled to the foot of the incline by horses, and then up the incline by cable.

The steam locomotive, like the steam shovel, is adapted for large plants, where large quantities of clay are in constant demand and must be hauled over considerable distances, perhaps to several different parts of the plant. Only one plant in the state uses a locomotive.

PREPARATION OF CLAY FOR THE MACHINE.

In many cases the clay when mined is not fit for molding; it is either too hard, too coarse, too fine, too strong, or too lean,

PLATE VI. — DAVIS' CLAY PIT, QUINNIPIAC.

A good example of a well developed pit, showing benches at further end, and graded bottom, which allows water to collect in the right front corner, where the pump is located. Clay is overlain by a few feet of peat.

and needs some preparation, as crushing, soaking, or tempering, before it can be made into a good quality of brick. In some places, the clay when mined is hard and lumpy and is left to weather. The weathering breaks up the lumps and renders the clay more plastic and easily worked. Shale especially requires weathering before being worked. Stones in clays should be eliminated, and are best removed by passing the clay through a disintegrator, a pair of rollers which crush the clay lumps and small pebbles and throw out the larger ones. The final step in preparation is the tempering of the clay, or the mixing with it of other materials to give it the requisite stiffness to retain its shape when molded. The tempering material or "grog" depends upon the natural resources. Where strong and lean clays exist in the same pit, they are often mixed; burnt clay is sometimes used; but the most common grog is the sand which overlies the clay. This is much preferred to other grogs, as it diminishes shrinkage, and less of it is required. At Parkville and West Hartford, and in some parts of Berlin, there is little or no overlying sand, and sand has to be carted from some distance, or the thin coating of surface loam or quicksand is used. This loam is far inferior to sand, and makes a weaker mixture, which requires a light machine for molding. Coal dust is also added to the clay before molding, but not to temper it. It becomes disseminated through the bricks, and, during burning, serves to distribute the heat more uniformly through the brick.

The tempering is sometimes done in a tempering pit, but more often in the pug-mill of the machine. The tempering pit is circular in shape, with a post in the center around which a tempering wheel revolves by either horse or steam power. The Connecticut brick clays are all too fine and moist to require any preparation except tempering, and that is done by the machine; so the clay requires but one handling.

CHARGING THE CLAY INTO THE MACHINE.

The material is charged into the top of the machine from a platform built over it, or by a clay elevator, which consists of an endless chain on sprocket wheels, carrying a series of buckets through a trough. The clay and sand are thrown

into the trough, taken along by the buckets, and dumped into the machine. Before the clay is dumped onto the platform, one-half the required amount of coal dust, usually three pecks to a thousand brick, or one peck to a load of clay, is spread over the floor. The grog is then added to the clay, the remaining half of the coal dust spread over the top of the heap, and the whole charged into the machine. The amount of grog varies with the clay: the strong clays require as much as one part of sand to two of clay, while the lean clays need no grog at all.

BRICK MACHINES.

Grinding and molding for common brick is done in Connecticut entirely by the "soft-mud" process, while a few yards, which manufacture hollow brick, use also the "stiff-mud" process.

Soft-mud Process. — The "soft-mud" process will be best understood by a general description of the "soft-mud" machine. There are several different types of machine, but all are modifications of the same general principle. The machine in general consists of three principal parts: first, the tub, horizontal or vertical, with knives projecting from the inner wall towards the middle, in which runs a shaft, also equipped with knives, and with a pair of wipers at its lower end; second, the press, which consists of a rectangular box on the front of the machine, in which a plunger moves vertically, pressing the clay into the molds; third, the table and appliances under the press box for holding the molds. The clay mixture is fed into the top of the tub, or, as is usually the case, into the disintegrator, and perhaps through an extra pugmill, attached to the top of the machine, for removing pebbles and giving more thorough tempering. The material is then forced along through the tub by means of the knives and wipers into the press box. The descending plunger of the press forces and presses the clay into the mold, after which the mold is pushed out to the front of the table, while another mold slides under the plunger. This movement is made from the rear of the table by means of arms of the rock-shaft, not visible from the front of the machine. An empty mold is inserted in front of these arms, which, as the plunger rises, move


THE IRON
QUAKER
BRICK MACHINE
PAT'D. MARCH 9, 80.
REIS'D JUNE 14, 81.

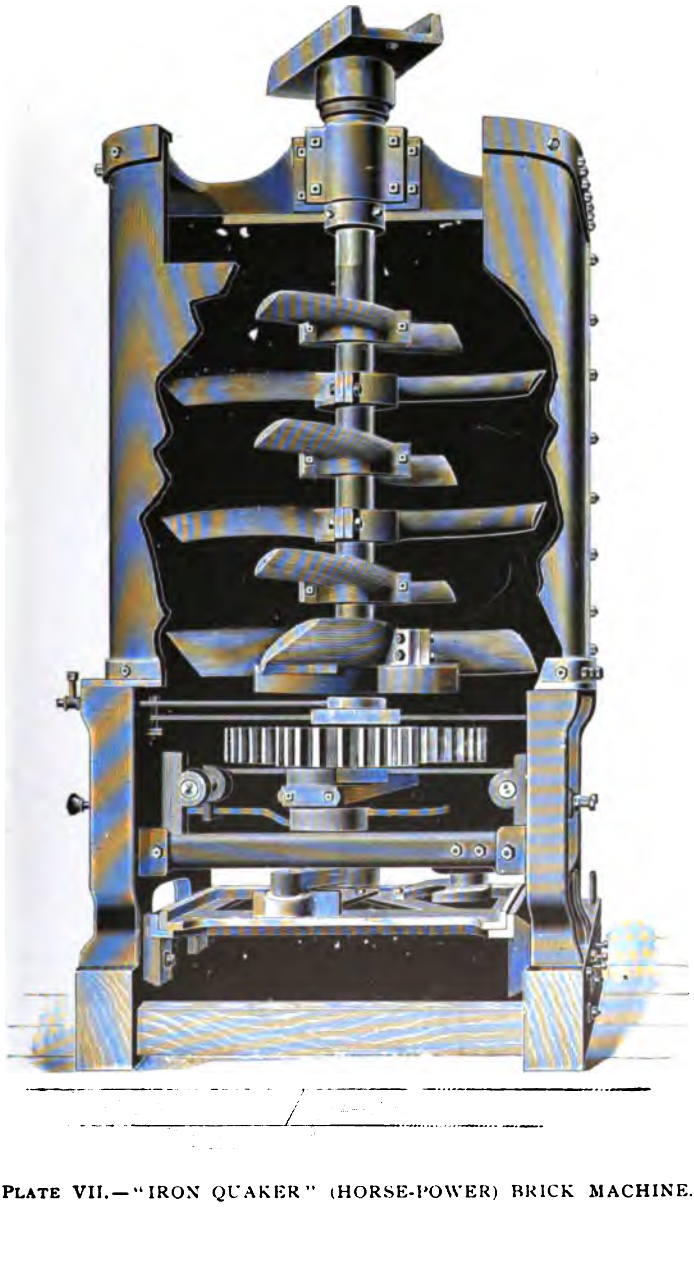
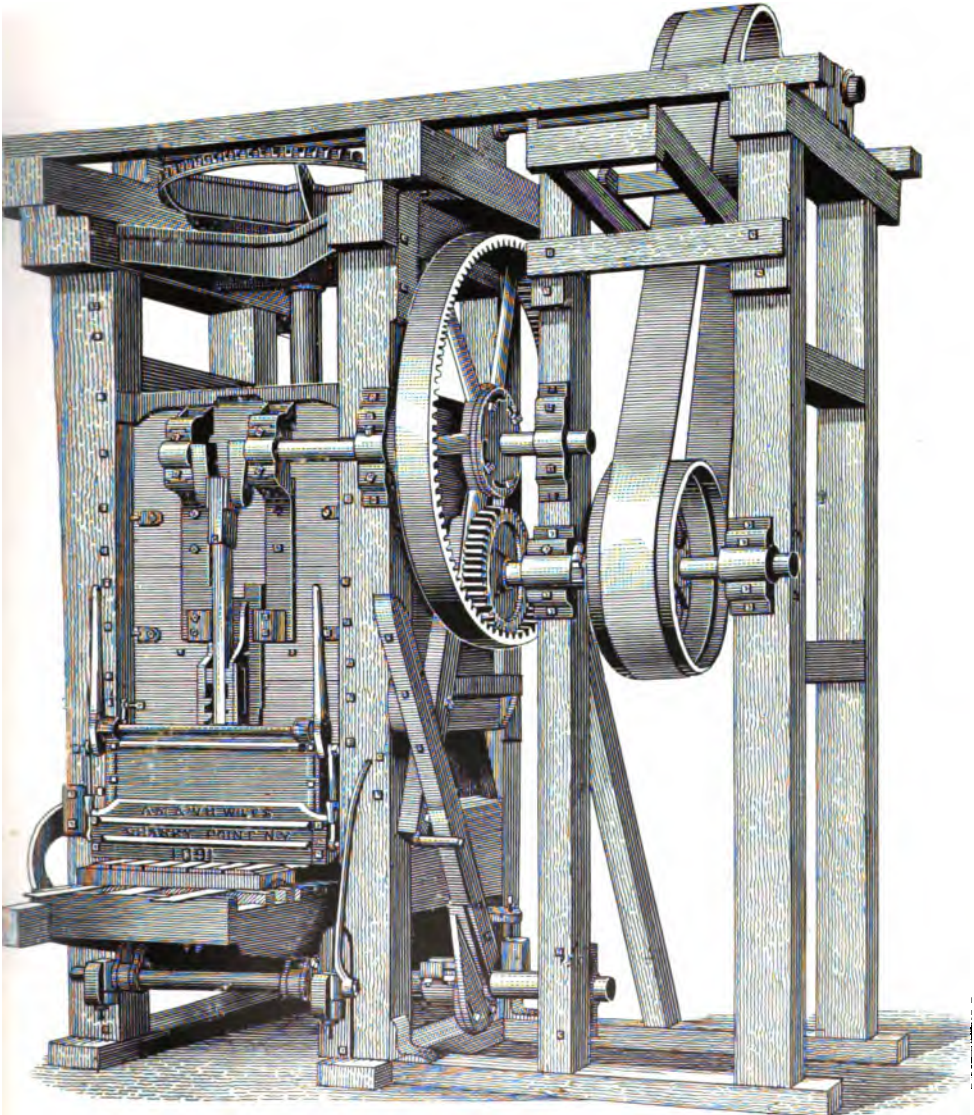


PLATE VII.—"IRON QUAKER" (HORSE-POWER) BRICK MACHINE.



H.MACHINE

PLATE VIII. — A. M. & W. H. WILES "H" MACHINE.

forward and push both the empty and the filled mold ahead of them to their respective places. On their return movement the rock-arms leave a gap into which the next mold is slid, and the process is repeated until the desired number of brick are molded. The backward and forward movement is effected by means of levers at the side of the machine, which are operated by cam rollers on the large vertical gear wheel.

The different types of machines are based practically on differences in the mechanical arrangement for driving the mud shaft and press, and for drawing out the filled mold. They range from light machines operated by horse power to large and heavy ones driven by steam or electric power. The larger machines temper the clay more thoroughly, use the clay in a drier condition, and press it harder; but they require more power to run. The size and power of the machine, then, depends principally on the stiffness of the clay, the size of the plant, and the choice of the individual brick-maker.

Plates VII, VIII, IX, and X show the varieties of soft-mud machines most commonly used in Connecticut. "The Iron Quaker" machine, plate VII, manufactured by the Wellington Machine Co. of Wellington, Ohio, represents a horse-power machine. It weighs 4,500 pounds, and makes 15,000 to 20,000 brick per day, with two horses and from five to seven men. It is six feet high, five and a half feet long, and three and a half feet wide. Five molds of six bricks each are turned out to every two turns of the horses. This machine is adapted for small yards.

The firm of A. M. and W. H. Wiles of Grassy Point, N. Y., has supplied machines for several of the smaller yards in the vicinity of Hartford. Plate VIII represents their "H" machine, which requires a ground area of ten feet by four feet seven inches. Its height from the center of the driving shaft to the base is twelve feet six inches; its weight is 15,000 pounds; the inside measurement of the tub is three feet five inches by three feet five inches; it is driven by steam and requires fifteen horse power; the line shaft is three and five-eighths inches in diameter, the mud shaft six inches, and the carriage shaft three and three-eighths inches. The latter is provided with slip joints to protect the carriage from break-

age, should anything get caught. The brick yards using the Wiles machines in 1903 averaged 20,000 to 21,000 brick per day.

Plate IX shows the style " B " machine, manufactured by the Henry Martin Brick Machine Manufacturing Company, Lancaster, Penn. It is used in some of the yards of the Quinnipiac area. In this machine the main upright, or tempering, shaft is extra heavy, and fitted with wrought-iron mixing knives; the crown gear is six inch face and two and a half inch pitch, with corresponding pinion; the spur gears are four inch face, the pinion being fitted with a friction clutch, allowing the machine to be started gradually and stopped instantly. The machine is equipped with an automatic mold protector, a friction relief, which prevents breakages in case a stone or other hard substance gets partly through the die and catches the mold, and an automatic self-strike, which cleans the tops of the molds as they come from beneath the press box. The machine weighs 8,000 pounds, is operated by steam, requiring ten horse-power, and has a daily capacity of 35,000 brick.

The three machines just described are all vertical machines. Maunfacturers emphasize the fact that in these machines gravity assists in feeding the clay towards the press box, thus avoiding the excessive wear caused by the necessity of requiring the tempering knives to force the material, and avoiding all end thrusts on the main shaft.

The largest and most commonly used machine in Connecticut is the " New Haven No. 2 " machine, plate X, built by the Eastern Machinery Company of New Haven, Conn. This machine consists principally of a long, horizontal pug-mill, with a vertical press attached to the front end, into which the clay is forced by direct pressure. The mold-pusher, which rolls on a covered track in the mold table, is operated in connection with the large press gear, the whole being driven by one belt on the side of the machine, while the tempering shaft is driven independently with one pair of bevel gears at the rear. The pugging chamber is thirteen feet long, thirty-two inches wide, and thirty-four inches deep inside. One heavily-ribbed casting forms the rear end of the machine and also the bearing for the tempering shaft. The front end is formed by

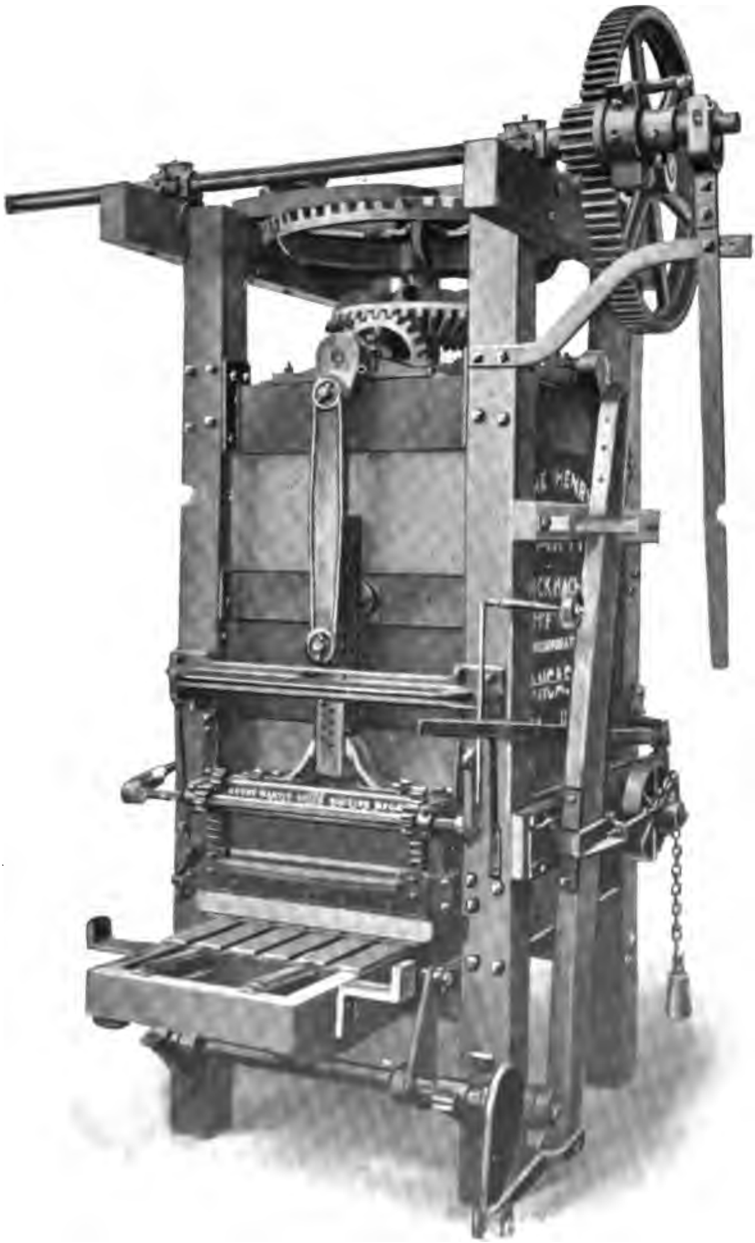


PLATE IX.—HENRY MARTIN "B" BRICK MACHINE.

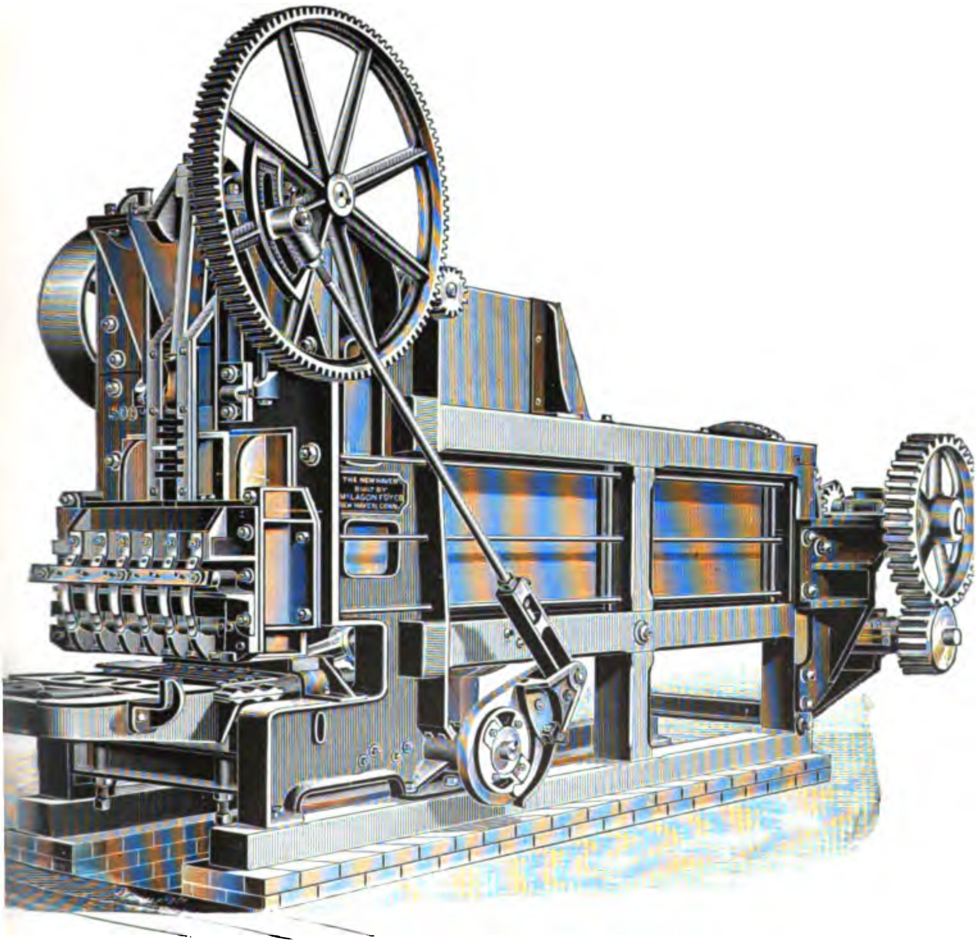


PLATE X. — NEW HAVEN No. 2 BRICK MACHINE.

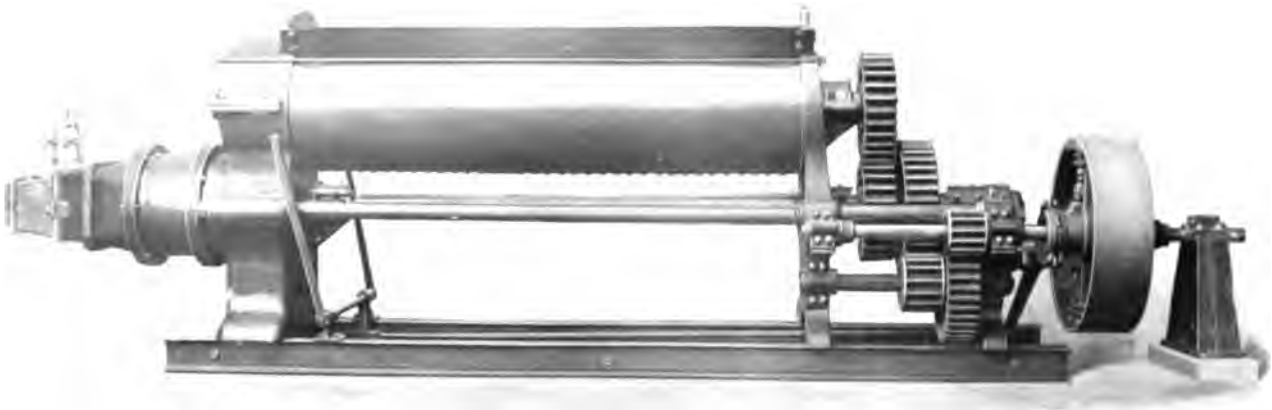


PLATE XI.—HENRY MARTIN "UNION" AUGER MACHINE.

two castings, of which the lower one supports the front end of the tempering shaft, while the upper one supports the steel press crank, and is secured against upward pressure of the press by heavy rods on each side of the crank pin. The whole front is held by the two side supports, which weigh over half a ton each. The advantage of the horizontal tub is that it is open at the top for its entire length, and enables the man who attends the tempering to see the exact condition of the clay until it enters the press, so that there is no reasonable excuse for not having the clay evenly tempered.

The vertical press is preferred to the horizontal or rotary presses, as it gives direct pressure and more power, thus filling all parts of the mold equally, and making bricks that will shrink uniformly during drying and burning. The press box is thirty-four inches long, ten and a half inches wide, and twenty-three inches deep, inside measurement. The unusually large depth permits extra space under the plunger for the clay to spread evenly and fill all the molds alike, while the direct pressure packs them solid.

The total weight of the machine is 17,300 pounds. It is operated by steam, or, in one instance, by electricity, and requires from twenty-five to forty horse-power, according to the quality and temper of the clay. The machine is adapted to work any clay, and its massive construction permits the working of the clay in a much stiffer condition with higher power than is possible with lighter machines. The capacity is ordinarily thirteen molds per minute, or 4,680 brick per hour. Most yards using this machine make from 45,000 to 46,000 brick per day of ten hours.

Stiff-mud Process. — The "stiff-mud" process is used in Connecticut chiefly for making a limited amount of hollow brick. The machine employed is called an auger machine, as the clay, after leaving the pugging chamber, is pushed through the die at the end by an auger. The die may be changed so that hollow brick, or front brick of different sizes, or tile may be made by one machine. The accompanying illustration, plate XI, of the Martin "Union" auger machine is sufficient to explain the working. The machine is made wholly of iron and steel; the pugging chamber is nine feet

long and two feet in diameter. It weighs 8,000 pounds, requires twenty-five horse power, and has a capacity of 20,000 to 30,000 brick per day.

The clay on emerging from the die is cut into the desired lengths by a wire, and so presents smooth surfaces, except on the ends. The chief disadvantage with auger machines is that the friction along the walls of the die retards movement of the clay, while in the middle it moves unhindered. As a result, the clay becomes laminated, and renders the brick liable to exfoliation.

Pressed-brick Process — Re-pressing brick is not carried on in Connecticut, although good pressed brick are said to have been made from Connecticut clays. Both soft-mud and stiff-mud brick may be re-pressed. In the dry press machine the clay is subjected to a very high pressure, and the resulting brick have very smooth edges and sharp corners. All clays do not work equally well in the press machine, as some crack when the pressure is released. Dry press methods, however, suit a great variety of clays, but require greater capital and equipment of plant, and a more thorough preparation of the clay.

MOLDING THE CLAY.

The manipulation of the molds in the soft-mud process is as follows: — The molds, each with six compartments, are first passed into a mold-sander — a trough in which are a series of revolving plates extending the full length, and in the bottom of which is placed fine sharp sand, dry and free from loamy matter. The molds are wet and placed on the revolving plates in such a way that the front edges of the plates, passing close to the wall of the trough, scoop up the sand, which slides over into the molds. As the mold comes up again, the surplus sand drops out. The mold is then tapped gently on the edge of the trough, jarring the still superfluous sand back into the machine, and is slid into the empty slot behind the press box. The fine sand, now coating the molds, permits the clay to slide easily from them. When the filled mold is pushed out onto the table, a man with a " brick-strike," or scraper, scrapes off the superfluous clay from the top. The mold is then taken

and dumped on a smooth, flat board or "pallet," which has been previously placed on a revolving dump table.

The revolving dump table is a wooden structure with four, five, or six leaves, on which the pallets are placed. The leaves work on spring hinges, and remain in a nearly vertical position until the newly molded brick are emptied onto the pallets, when they fall to horizontal. The bricks are carried half way around the circuit of the table, where the pallets are removed onto trucks.

Both the mold-sander and the dump table are usually connected by belts to the brick machine, so that all the machinery is operated by one engine and one main shaft. The dump table is so connected that it stops for every mold as it is sent out from the machine.

The trucks carry as many as nine pallets apiece. When a truck is loaded it is wheeled to the pallet racks, long covered rows of supports, on which the pallets are placed to dry. When the open-yard method for drying is employed, the molds are loaded directly onto the truck, and the .brick emptied on the drying floor.

The whole process of molding is a continuous repetition and rotation of the molds, and varies slightly at different yards. The number of men necessary for the operation depends upon the size of the plant and the rapidity of molding. In yards using the "New Haven" machine the following number will easily make 45,000 pallet brick per day, at the rate of twelve to thirteen molds per minute: —

1 man to feed and temper the clay,
1 man to strike off the molds,
1 man to tend sander and feed molds,
2 men to dump brick on pallets,
3 men for truckers,
1 boy to wheel empty pallets to machine,
1 boy to place pallets on dump table,
1 boy to wash molds, etc.
Total, 9 men and 3 boys.

DRYING THE BRICK.

Two methods of drying are employed in Connecticut: the pallet system, and the open-yard. A third method, steam-drying, was attempted, but it did not prove successful.

The open-yard method is generally used at the smaller yards, where lighter machines are used; but several of the larger plants have small spaces reserved for open-yard drying. The open-yard method is adapted to clays that are not stiff enough to be molded in a heavy machine, or to retain their shape while slowly drying on the pallets. The brick are dumped from the molds onto a flat rolled surface, and left to dry in the sunlight. The sun's rays, striking more directly upon the upper part of the brick, evaporate the water more rapidly from the upper surface, and cause uneven shrinkage. Half a day of bright, uninterrupted sunlight will cause a marked difference in shrinkage between the top and bottom surfaces of the brick. After they have dried sufficiently, a man with a tool called an "edger" turns the brick, six at a time, onto their narrow surfaces. Another man follows with a "spatter," a flat board fastened perpendicularly to a long handle, and spats, or evens up the brick, by striking a vertical blow on the narrow, inclined surface, making it horizontal, and restoring the rectangular shape of the brick. Spatting requires a careful workman, as one misdirected blow will spoil six brick.

As soon as the spatted brick are dry enough to handle, they are "hacked," or piled on edge in single rows, about twenty brick high, each row resting on a row of planks, and covered by a wooden saddle, as shown in plate XII. These hacks are left to dry from four days to a week or more, according to the dry or moist condition of the air, and are then ready to be set in the kiln. In wet weather the hacks are protected by sheets of canvas hung along their sides. The chief disadvantage of the open-yard method is the danger of exposure to rain. An unexpected shower or a rain coming up in the night sometimes ruins a whole yard of brick. Excessive heat may, in some cases, cause cracking from too rapid shrinkage.

The pallet-and-rack system is decidedly superior to the open-yard, when the molded clay is sufficiently stiff. In this method, the pallets are set in tiers under long narrow roofs.

PLATE XII. — KANE'S BRICK YARD, PARKVILLE.

Shows plan of brick yard, using open-yard method of drying. Bricks are molded in machine at right front of picture, dried in yard, where they are seen in "hacks," and thence taken to the kilns under the shed at the rear.

Little or no sunlight reaches the brick, except on the end row, and the drying is accomplished by the circulating air. This circulation of air causes more rapid drying than takes place in the open yard, and the brick on the racks cannot draw up any moisture from the ground. As soon as the green brick are sufficiently stiff, they are edged, usually by hand, and left till ready for burning. Pallet brick usually require from four to seven days to dry, but in very wet weather they may require two weeks or more.

The roof and temporary shelters, which can be let down over the sides of the racks, protect the brick from rain and excessive heat, except in sudden storms, when the bricks in the end row may suffer before they can be covered. In case of frost, however, both open-yard and pallet brick suffer equally, as the water still in them bursts them by freezing. For this reason, the brick yards can be operated only between April and October, or during the season between the earliest and latest frosts.

The steam-drying process is more rapid and more expensive than the two preceding methods. There are several different types of steam, or hot air, driers which all present the same diffculty of the uniform circulation of heat throughout. This defect and the extra cost of fuel necessary to run them prevent their more extensive use. Their principal advantage is that they will dry the brick in any kind of weather, and require only one or two days to dry them sufficiently for burning.

BURNING THE BRICK.

All the brick in Connecticut are burned in temporary up-draft, or "scove" kilns. A few yards have used stationary up-draft kilns, but none were in use at the time of the writer's visit. The scove kilns are built of the green brick. Arches are built at the base for the fires, and the bricks above are set slightly apart so as to afford a circulation for the heat. Kilns are usually built about fifty brick high, and are erected under open sheds. The walls are of "double-coal" brick, containing a large amount of coal dust, which is supposed to draw the heat to the walls, and produce a uniform burn. Burned brick are often used with double-coal brick for the walls. The walls, when completed, are plastered with mud, making the kiln air-

tight on all four sides, and leaving the heat to escape at the top. The kiln walls are supported by strong frames, which prevent them from bulging out during the burning.

The only fuel used in Connecticut is wood. The fires are started very slowly, to evaporate out what included water still remains in the clay, and incidentally to give a more thorough oxidation to the iron. The temperature is then raised to red heat, and must be maintained at that temperature until the chemically combined water is expelled. The heat is then increased more rapidly, and kept at high temperature until the end of the burn, when the fires are allowed to die slowly down.[1]

Six to seven cords of wood are usually consumed in each arch, and the whole process of burning lasts about a week, or until the top of the kiln has settled a certain distance. This distance varies with the stiffness and degree of shrinkage of the clay; but, with the soft-mud brick of Connecticut, it is usually from ten to twelve inches, and is indicated by "tell-tales," or burned bricks hung from above so that they just touch the top of the unburned kiln.

The maximum heat in kilns of this type is obviously at the arches, and gradually diminishes towards the top; so, to give the uppermost bricks a thorough burning, the arch bricks must be greatly overburned, and are often found, after a burning, to have sagged, or even to have melted together. The exceedingly hot flame also has a reducing effect on the iron at the temperature of fusion, and produces the black color common to arch brick; though the black may be caused on the surface of an unfused brick by an insufficient supply of air, a smoky flame, or small particles of ash that fly up and stick to it.

The following figures, determined by Wheeler,[2] show the temperatures at which different colors are produced:—

The brick becomes

Dull salmon (at red heat)	1000° to 1200°F.
Deep salmon	1300° to 1400°F.
Light red (bright red heat)	1500° to 1600°F.
Deep red	1800° to 1900°F.
Very dark red (cherry red heat)	2000° to 2200°F.
Fuses and turns black at	2300°F.

[1] For details of behavior of clay during burning, see p. 48 in Part I.

[2] Mo. Geol. Surv., Vol. XI, 1896, p. 482.

Owing to the low fusing point of the Connecticut clays, these figures are undoubtedly high; but they serve to show the wide difference in the temperature through a kiln in which the top brick are only of salmon color, while the arch brick are fused. Such great difference in temperature is the great disadvantage of the scove kiln. A strong breeze blowing against one side of the kiln will cool the thin walls, and drive the heat to the other side, thus causing an uneven burn, while the very structure of the kiln makes uniform heating throughout impossible. The advantage of the scove kiln is that the burned brick may be left in the kiln till shipped.

The permanent up-draft kiln is built of burned brick, with solid walls on three sides, and with the fourth side open to facilitate removal of the brick after burning. The advantage claimed for the permanent up-draft kiln is that the bricks are more thoroughly and uniformly burned, a fact which should balance the extra cost of the kiln. Most manufacturers in Connecticut seem content with the temporary scove kiln, and the production of under-burned along with the well-burned brick. Only one permanent kiln stood in 1903, and that was not in use. It had been used for burning stiff-mud brick.

Down-draft kilns are not used in Connecticut at all for common brick manufacture. In these kilns the heat enters at the top, passes down through the stacked brick, and out through flues at the bottom. The fire does not reach the brick, and, it is claimed, can be more easily controlled so as to give a uniform heat.

REMARKS ON BURNED BRICK.

The dark red brick at or near the bottom of the scove kilns have undergone incipient, or in some cases almost complete, fusion, and become impervious; they are generally classed as sewer brick on account of their impervious character. The deeper colored brick are suitable for the outer walls of buildings, while the pale, under-burned brick should, on account of their high degree of porosity, be restricted to the inner parts of walls, out of contact with the atmosphere.

Many brick-makers do not separate the pale brick from the dark, and their sole object seems to be simply to sell the

brick. As a result, brick of several grades of quality are laid side by side in the faces of walls, and the difference in weathering after a few years is very noticeable. While the thoroughly burned bricks have suffered no visible change, the surfaces of paler brick have often become roughened, and the corners and edges have become rounded from disintegration due to weathering. The contrast is often enough to spoil a building's appearance.

In sidewalks the contrast in wearing under abrasion and weather combined is even more noticeable. While the black and dark red bricks show very little wearing, the pale colored bricks are worn into hollows which are often deep enough to render walking very uncomfortable, especially on rainy days, when each hollow becomes a puddle. For a sidewalk in a city, where hundreds of people pass every day, only the most thoroughly burned brick, such as sewer or black arch bricks, should be used, as by their partial or complete fusion, they practically fill the requirements for paving brick where the traffic is not too heavy. Pressed brick are better still, as their uniform color gives a better appearance; but their smooth surfaces are liable to make slippery walking in frosty weather.

Fancy brick are simply common or pressed brick molded into special shapes. They are used for ornamental work along with common building brick. Pressed and vitrified brick have been occasionally made from the local clays, but the demand for them is very small. Hollow brick are made by a few firms, but generally only to fill special orders. The hollow brick are used for fireproofing.

The principal loss in a burned kiln is the swelled bricks. The swelling has been explained in Part I as due to too rapid heating, without allowing sufficient time for drying, or for the escape of gases from coal dust, carbonates, or sulphates. Sometimes the swelling is due to the placing by mistake of undried or double-coal brick in the middle of the kiln. The black color commonly seen in swelled bricks is probably due to the reduction of the ferric oxide by the burning carbon. The carbon, unable to get oxygen from the air, has to take it from the iron, forming first carbon monoxide and finally the dioxide, leaving the black ferrous oxide in the brick. The

darker color of the inside of red bricks may be due to partial reduction of the iron by the coal dust.

MANUFACTURE OF FIRE-BRICK.

The fire-brick industry in Connecticut is limited to one firm, which manufactures fire-brick goods of all kinds — brick, stove and furnace linings, etc. The clays used are the Woodbridge and Raritan River clays of New Jersey. The tempering sand is taken mostly from New Jersey and Long Island. A little local sand is used; but, owing to its high percentage of silicates, it is hardly refractory enough for refractory ware, which should withstand a temperature of over 2,500° F.

A very great variety of goods is manufactured, and the company has on hand from 3,000 to 4,000 molds. The tempering is done by the soft-mud process, and the molding principally by hand, as the shapes of the goods are mostly such that they cannot be molded by machinery. The burning is done in a down-draft kiln, at a maximum temperature of 2,500° F. The plant has no regular capacity, but fills the various orders as they come.

CHAPTER III.

The Manufacture of Pottery.

The pottery industry in Connecticut is small. There is only one large firm, while two or three others do business on a small scale. Earthenware and stoneware are manufactured, the earthenware from native clay, the stoneware from New Jersey clays.

Earthenware. — The only large pottery plant in the state is engaged in the manufacture of plain and fancy earthenware. Common brick clay is used without mixture of other materials. After mining, it is soaked to a desired softness, and then put through a small grinding machine, in which a revolving vertical shaft with blades attached tempers the clay, and a screen at the bottom catches the stones. The clay is delivered at the bottom in sheets, which are then rolled up into balls and taken to the potters. These men shape the clay in molds revolving rapidly on potters' wheels. It requires but a few seconds for a skillful potter to mold the simpler articles. The filled molds are set on shelves to dry. The molds are made of plaster of Paris, to which the clay will not adhere, and which readily, and gradually, absorbs the moisture from the clay, so that in from half a day to a day the clay will have shrunk wholly away from the mold. The mold is then taken apart, and the green clay vessel is left to dry sufficiently before being set in the kiln.

The drying floor is in some cases situated over the kiln, and at night the floor is opened, admitting the heat, which hastens drying. At some potteries the ware is dried over steam or hot air pipes.

If the clay is too moist when burned, it explodes, and, if burned too long, it vitrifies and sags, ruining the ware. The burning generally lasts for two days. The down-draft kiln is generally used, and both coal and wood may be used for fuel.

After burning, the fancy ware is sent to be decorated. The

decorating is all done by hand, and, with the molds of various shapes, produces an endless variety of goods.

Stoneware. — There is only one firm in the state which manufactures stoneware. The South Amboy clays of New Jersey are used. The process of molding is principally by hand, as the shapes of the goods are such that molds cannot be conveniently used. The clay is placed on a revolving disc, or wheel, and the potter, by "feeling" the clay, that is, by working it into a position where its natural tendency to slump on account of its plasticity is just balanced by the centrifugal force generated by the rotation, brings it to the desired shape.

Different mixtures of clay are used for different kinds of ware. The dark glaze on the interior of the ware is produced by a slip clay from Albany, N. Y. The clay is made into a thin paste, and sprayed over the inner surface of the ware by a force pump. Its relatively low and rapid fusion causes it to melt and soak into the pores of the stoneware clay, making an impervious body. The glaze on the outer surface is produced by common salt, which is put into the top of the kiln, melts, and runs down over the surfaces, uniting with silica and forming the glaze. The chlorine gas from the salt is driven off at the top of the kiln. The maximum temperature in burning is somewhere above 2,000° and below 2,500° F., as the liquid fusion of the slip probably cannot take place much below 2,000°, and the heat at 2,500° is so great as to cause the slip to begin to vaporize, and ruin the glaze.

Products no Longer Manufactured. — There formerly was a manufactory of white ware at New Milford, but it has not been operated since 1903. Drain tile and sewer pipe also have been formerly manufactured at several localities, but both industries, as far as the use of clay is concerned, have been idle for some years.

CHAPTER IV.

The Condition of the Clay Industries of Connecticut.

The abundance and similarity of the brick clays in Connecticut, and the small profit made on clay products, limit the location of plants either to areas where a railroad crosses a clay area, and shipment can be made directly from the kiln to the freight cars (Plate XIII), or to the neighborhood of the large cities, which can consume the output. For this reason, many square miles of good clay deposits in the rural parts of the state are untouched.

The general tendency of the brick-makers seems to be to cling to the old, often unprofitable methods of manufacture, rather than to investigate and attempt improvements of any kind. Improvements have been attempted in a few cases unsuccessfully, and these failures, along with lack of capital, may account for the present lack of enterprise. The quality of the clay is such as to encourage improvements; and success in attempted improvements then depends partly upon the quality of the apparatus, but principally on the skill and judgment of the clay worker.

Some brick-makers prefer to employ unskilled labor, which they can turn to any kind of work at low wages, rather than to employ skilled labor at greater expense for the special work that some improvements would require. Such facts are important, especially in yards of not very great capacity; but improvements, especially in the quality of brick produced, may lead to enlargement of the plant. No improvements can be made without experiments and expenditure of time and capital, and the returns will not follow immediately, but will probably increase after they begin. The native clay is certainly capable of turning out a better quality of brick than is made today, if more care is taken in the tempering and burning. The large percentage of under-burned brick that are sold with

PLATE XIII. — KILN SHEDS BELONGING TO SHARES' BRICK YARD, QUINNIPIAC.

Spur track runs under the sheds, and bricks are loaded directly into freight cars.

well-burned brick must obviously detract from the quality of the brick as a whole. Unless the builders prefer to use poor brick at low cost, there is no reason why the quality of brick should not be raised even at an increase of cost.

The chief difficulty with the manufacture of any other than common brick on an extensive scale is that the output of other states already supplies the market. It is very probable that the Connecticut clays can make good pressed and vitrified brick, but they cannot compete with the reputation already established in other states. But, here again, no reputation can be made without a considerable expenditure of time and money.

STATISTICS OF THE CLAY INDUSTRIES.

The following tables of the brick and pottery maunfacturers will give a general idea of the extent of the clay industries in the state:

BRICK MANUFACTURERS.

Locality and Name of Manufacturer.	Number of Men Employed.	Capacity (Brick per day).	Varieties Manufactured.	Method of drying.	Kind of Power.
Thompsonvile Dist.					
Alden's	21	22,000	Common	Pallets	Steam
Windsor Dist.					
Wilson's	(av.) 38	44,000	Common	Pallets	Steam
Baker's	5	10,000	Common	Pallets and open yard	Horse
Curtis'	(Not running in 1903.)		Common and hollow		Steam
Mills & Son's	12	20,000	Common	Open yard	Steam
March's	5	12,500	Common	Open yard	Steam
So Windsor Dist.					
E. Windsor Hill Brick Co.'s	40	45,000	Common	Pallets	Steam
Meed & Mullaly's	16	20,000	Common	Open yard	Steam
Parkville Dist.					
Kane's	20	21,000	Common	Open yard and pallets	Steam
Dorr's	20	21,000	Common	Open yard and pallets	Steam
Electric B. Co.'s	20	21,000	Common	Open yard and pallets	Steam
Dennis's	(Not running in 1903.)				
Elmwood Dist.					
Park B. Co.'s	45	45,000	Common	Pallets and open yard	Steam
Hartford B. Co.'s	40	45,000	Common	Pallets	Electricity
Clayton Dist.					
New Britain B. Co.'s	35	46,000	Common	Pallets	Steam
Dennison's	(No information received.)				
Berlin Dist.					
Murray's	53	46,000	Common	Pallets	Steam
Berlin B. Co.'s	48	46,000	Common	Pallets	Steam
Towns Bros.'	48	46,500	Common	Pallets	Steam
Donnelly's	46	46,000	Common	Pallets	Steam
Merwyn's	90	90,000	Common and hollow	Pallets	Steam
Standard B. Co.'s.	45	47,000	Common	Pallets	Steam
W. L. Davis'	54	47,000	Common and hollow	Pallets	Steam
Holmes'	(No information received.)				
American B. Co.'s	47	47,000	Common	Pallets	Steam
Middletown Dist.					
Clark's	(Not running in 1903.)				
Tuttle's	(No information received.)				
Johnson's	35	40,000	Common	Pallets	Steam

BRICK MANUFACTURERS—*Continued.*

Locality and Name of Manufacturer.	Number of Men Employed.	Capacity (Brick per day).	Varieties Manufactured.	Method of drying.	Kind of Power.
Quinnipiac Dist.					
Stiles & Son's [1]...	200	150,000	Common	Pallets	Steam
Brockett's........	(No information received.)				
Share's [1].........	80	85,000	Common	Pallets	Steam
W. E. Davis' [1]....	50	70,000	Common	Pallets	Steam
Milldale					
Clark Bros.'......	18	20,000 [3]	Common	Pallets	Steam
Total........	1,131 [2]	1,153,000 [2]	....	....	....

Average wages per day, $1.00 to $2.00. Length of day, ten hours.

The only firm manufacturing fire-brick is that of Howard and Company, New Haven.

Only two operating firms producing pottery furnished any data. These two firms are: Goodwin Bros., Elmwood, 40 men, plain and fancy earthenware; John O'Halloran, New Haven, 7 men, earthenware and stoneware.

The value of the clay products of Connecticut from 1894 to 1903, inclusive, is shown in the following table, compiled from the United States Geological Survey's annual report on the Mineral Resources of the United States. The amount in the table contributed by Rhode Island is not enough to alter the significance of the figures:

[1] Operates two yards.

[2] Yards not reported aggregate a little over 100 men, and about 135,000 brick per day.

[3] Not steadily operated.

7

CLAY PRODUCTS OF CONNECTICUT AND RHODE ISLAND, 1894–1903.

Product.	1894[4]	1895[4]	1896[4]	1897	1898	1899	1900	1901	1902	1903
BRICK										
Common										
Quantity	100,300,000	18,550,000	166,995,000	200,130,000	120,380,000	150,665,000	164,431,000	161,696,000	156,885,000	158,382,000
Value	$549,650	$642,462	$9[illegible],738	$1,017,250	$670,880	$751,839	$862,334	$822,070	$8[illegible]6,171	$890,989
Average per M	$5.48	$5.41	$5.79	$5.00	$5.57	$4.99	$5.24	$5.10	$5.71	$5.62
Pressed										
Quantity		150,000	90,000	3,200,000	a	a	a	a	a	a
Value		$4,500	$1,900	$89,400	a	a	a	a	a	a
Average per M		$30.00	$21.11	$27.93	$15.37	$8.78	$15.08	$15.04	$9.09	$15.04
Vitrified										
Quantity	10,000	....	20,000	4,015,000	a	a	a	....	a	a
Value	$250,000	....	$400	$50,270	a	a	a	....	a	a
Average per M	$25.00	....	$20.00	$12.52	$12.58	$10.00	$12.00	....	$9.10	$14.03
Fancy or Ornamental										
Value	$5,000	$600	....	$16,500	a	a	a	a	a	a
Fire										
Value	$57,000	$64,000	$71,800	$44,750	a	a	a	a	a	$61,500
STOVE LININGS										
Value	....	....	....	....	b	a	....	a	$12,750	
DRAIN TILE										
Value	$500	$1,000	$14,100	$1,000	....	....	a	....	....	....

SEWER PIPE Value	$15,000	$4,500	$2,460	....	....	....	a	....	....	....
FIREPROOFING Value	....	....	$500	$21,000	a	a	a	a	a	a
TILE (not drain) Value	$5,000	....	$15,000	$15,000	a	....	a	....	....	....
ORNAMENTAL TERRA COTTA Value	$60,100	$44,563	$30,000	$10,000	....	....	....	....	....	....
POTTERY Earthenware and Stoneware Value	....	$2,800	{ $33,460 $13,240	$71,500	$16,100	$53,250	$44,250	$48,200	$48,100	$42,250
Miscellaneous[c] Value	$24,000	$67,500	$2,000[e]	....	$261,200	$269,713	$193,388	$260,630	$260,657	$211,330
Total value	$717,000	$831,925	$1,119,920	$1,336,670	$948,180	$1,074,202	$1,099,972	$1,130,909	$1,217,678	$1,206,069
Number of firms operating	44	44	47	....	48	45	47	45	41	41
Rank of Conn. and R. I.	19[d]	20[d]	11[d]	10	16	20	20	21	21	23

a Included in miscellaneous.

b Stove lining not separately classified until 1899.

c Includes all products not otherwise classified, and those made by less than three producers, in order that the operations of individual establishments may not be disclosed.

d Rank of Connecticut alone.

e Porcelain and china.

These values show a continual fluctuation in the past nine years. The most profitable year was 1897, and was followed by a considerable slump in 1898. Then followed a steady increase up to 1902, while 1903 shows a decline of $11,609, which is confined to the pottery and miscellaneous. But, while the total value of clay products in Connecticut has remained fairly steady, about $1,000,000, those of other states have been steadily increasing, so that, while in 1896 Connecticut alone ranked eleventh in the United States, in 1903 Connecticut and Rhode Island together rank only twenty-third. The advance of the western states is due to the formation of large, well capitalized companies, which can employ chemists and other men with professional training to experiment with their materials and determine accurately what processes and mixtures will give the best results and at what temperatures; and until manufacturers, even of common brick, establish more thorough and careful methods, they cannot compete with the western states. Connecticut has the materials, but needs more careful methods of manufacture and a market for goods of better quality.

Index.

A

F

N

O

P

S

PAGE.

Y

Z

State of Connecticut

State Geological and Natural History Survey

BULLETIN No. 5

THE USTILAGINEÆ, OR SMUTS, OF CONNECTICUT

By

GEORGE PERKINS CLINTON, S.D.

Botanist of Connecticut Agricultural Experiment Station

State of Connecticut

PUBLIC DOCUMENT No. 47

State Geological and Natural History Survey

COMMISSIONERS

HENRY ROBERTS, Governor of Connecticut *(Chairman)*
ARTHUR TWINING HADLEY, President of Yale University
BRADFORD PAUL RAYMOND, President of Wesleyan University
FLAVEL SWEETEN LUTHER, President of Trinity College *(Secretary)*
RUFUS WHITTAKER STIMSON, President of Connecticut Agricultural College

SUPERINTENDENT

WILLIAM NORTH RICE

BULLETIN No. 5

HARTFORD PRESS
The Case, Lockwood & Brainard Company
1905

THE USTILAGINEÆ, OR SMUTS, OF CONNECTICUT

By

GEORGE PERKINS CLINTON, S.D.

Botanist of Connecticut Agricultural Experiment Station

HARTFORD PRESS

The Case, Lockwood & Brainard Company

May, 1905

The Ustilagineæ, or Smuts, of Connecticut.

GENERAL CHARACTERS OF THE SMUTS.

The Ustilagineæ are an order of parasitic fungi commonly known as the smuts, of which corn, oat, and onion smuts are familiar examples. See Figs. 55, 43, 42. Thus the more evident characters of these fungi are the black, dusty masses that break out on the surface of the infected plants (hosts). In these macroscopic characters the smuts are often very similar to the rusts, but with a little experience one can readily distinguish them from these even with the naked eye. The dusty *uredo* stage of the rusts, for instance, is of a lighter reddish color, and the darker *teleuto* stage is usually more firmly embedded in the plant tissues, than are the smuts. Not all of the smuts, however, produce dark dusty outbreaks, since the white smuts are light colored and usually permanently embedded in the tissues of the host. Generally they occur in the leaves, and often are distinguished by light colored spots produced without distortion of tissues. More experience is needed to distinguish these forms. See Figs. 29-34.

The smuts occur on a great variety of flowering plants, and at least 35 different families of plants in North America and 17 in Connecticut are subject to their attack. The grasses, however, are by far the most frequent hosts. Between 500 and 600 species of smuts have been described from different parts of the world, and over 200 of these occur in North America. The number of species known from this state * is 50, and these represent 12 of the 19 genera reported from North America. While time no doubt will reveal a few more species and a greater number of hosts not reported here, we may still consider the group rather thoroughly worked up, since, as yet, only one other state has reported a greater number of species.

---

* The list of smuts reported in this paper is based chiefly on the collections made by the writer during the past three seasons. Specimens of these are to be found in the herbarium of the Conn. Agr. Exp. Station at New Haven and in the writer's herbarium. Collections made by others are indicated in each case by the name of the collector.

LIFE HISTORY OF THE SMUTS.

In the study of these fungi, there are three parts that we need to consider, namely, the *mycelium*, the *spores*, and the *sori*.

Mycelium is the technical name for the vegetative part of the smut, by means of which it spreads through its host and gathers nourishment. This consists of microscopic threads confined to the interior of the host, so it is necessary to examine very thin cross sections of the tissues under the microscope to see this stage. See Fig. 26. These threads vary but little with the different species, and therefore are of no value in classifying the different species. They are simple, hyaline, more or less branched, and at first filled with protoplasmic contents, but gradually lose most of their contents and become septate. They push their way between the cells of the host or sometimes through them. Usually, however, they enter the cells only by short special branches called *haustoria*, whose special function is to gather nourishment from the cell. The mycelium may be localized or rather generally spread through the host. In those cases where it gains entrance through the germinating seed, it usually remains evident finally only at the nodes or where it breaks forth to the exterior in its fruiting stage. In perennial plants the mycelium often becomes established in the perennial parts, from which each year it sends threads into the new growth.

Eventually the mycelium becomes prominent in certain regions of the host, and there undergoes special modification to give rise to the reproductive or spore stage. The walls of the mycelial threads that form the spores are generally indistinct through more or less complete gelatinization. The spores are usually formed from contents in the interior of these fertile threads. This gelatinization apparently serves to nourish the developing spores, as often all signs of the threads disappear on maturity of the spores. In some cases, as in the genus *Neovossia*, Fig. 13, and often in *Entyloma*, however, these threads remain as more or less evident envelopes to the spores.

Spores are the bodies by which the smuts reproduce themselves. See Figs. 1-20. They are the evident, usually ex-

ternal part of the fungus, making up the smutty masses visible to the naked eye, and are the characteristic and variable parts upon which species are based. The spores are usually so formed that at maturity they break out to the exterior of the host in a dusty mass that is easily scattered, thus securing their dispersal. In some species, however, they are embedded in the host so that they are liberated only on the rotting of the tissues, and sometimes they germinate *in situ,* and secure their dispersal by the formation of secondary spores of a different nature. While easily seen in mass, the spores are really microscopic in size, varying according to species from 4μ to 35μ.* They are usually subspherical or spherical, but vary to ovoid, ellipsoidal, or even oblong. Pressure often makes them more or less polyhedral, or irregularly so. They are generally simple, consisting of single separate cells; but are sometimes bound more or less permanently into spore balls, Figs. 7*a*, 10*a*. These spore balls may consist entirely of fertile cells (spores) or they may have an external coating (cortex) of sterile cells, Fig. 19, or an internal matrix of sterile cells or even of threads, Fig. 20. The spore walls may be smooth, or marked with minute spines (echinulations if sharp, verruculations if dull), or reticulated with a net-work of ridges or wings. In color they are hyaline, yellowish, reddish or olive brown, violet, or purplish. Often the color is so deep that the spores are opaque or nearly so. Upon these variations the genera and species are chiefly classified, though on the whole the variations are not so great as with many of the other fungi. This is partly due to the fact that the spore-producing threads are not diversified or permanent.

In some few species, most frequently in the genus *Entyloma,* the mycelium also gives rise to secondary spores called *conidia.* These are usually hyaline, elongated, ephemeral, and are produced originally on the exterior of the host, generally from mycelial tufts protruding through the stomates and forming these conidia at their tips. Their object is to spread the smut over the host or to new hosts immediately.

Sori are the evident masses of the spores that break out singly or in clusters on the various parts of the hosts. See

* A μ, or micron, is one twenty-five thousandth of an inch.

Figs. 27-55. These are protected more or less permanently by thin coverings of plant tissue, or in some genera, as *Sphacelotheca,* and often in *Cintractia,* by false membranes composed chiefly of fungous cells or threads, Fig. 5a. The sori vary greatly in size, sometimes forming outbreaks smaller than a pin-head, and sometimes, as often in corn smut, reaching several inches in diameter. Usually each species has a definite place on its host where the sori appear. This may be on the leaves, Fig. 35, on the stems, Fig. 28, in the blossoms as a whole, Fig. 54, or confined to the anthers, ovaries, Fig. 52, or seeds, Fig. 48. Occasionally a smut may break out in any of these places. In the grasses, when infecting the inflorescence, the sorus may be confined to the ovary, infest the spikelet as a whole, or even involve the entire inflorescence. Sometimes all of the ovaries or spikelets are infested and sometimes only part of them. The characters of the sori, of course, are modified somewhat by the part of the host in which they develop, and also by the kind of host on which the smut occurs. Usually the sori are dusty and easily dissipated. With a few species they are hard, and the agglutinated spore mass is disseminated by gradual disintegration, often through the absorption and loss of water. In these cases there is sometimes a gradual ripening of the spores from the outside of the sorus inward. With some genera (*Entyloma, Doassansia,* etc.) the sorus is rather permanently embedded in the tissues of the host, usually in the leaves, and often produces only a discoloration of these. The species of one of the European genera form gall-like growths in the roots.

Germination of Spores. There are two chief types of germination of the Ustilagineæ upon which the two families are based. In the *Ustilaginaceæ,* Fig. 21, the spores, when placed in a drop of water, send out a single, hyaline thread, several times their length, which usually divides into about four cells by cross partitions, or septa. This is called the *promycelium.* Usually at the apex of each cell one or more elongated thin-walled spores, or *sporidia,* are budded out, the apical cell bearing its sporidium terminally and the others laterally. The sporidia when full-sized are pinched off at the base, and others are sent out until the protoplasm of the cell

is exhausted. These sporidia germinate by a short slender thread (infection thread) that usually pushes out from near one end, Fig. 24. In some species the cells of the promycelium, instead of forming the sporidia, give rise directly to the infection threads, Fig. 23. Sometimes the adjacent cells of the promycelium become connected by closely applied short threads, forming buckle or knee joints, and from these may develop infection threads. Some species germinate directly into elongated threads which scarcely partake of the nature of a promycelium. When nutrient is added to the drop of water, the spores germinate much more luxuriantly, the sporidia usually sprouting out other sporidia while still attached to the promycelium. Especially in a solid cultural medium these chains develop a more or less complicated system of branching, Fig. 25. In a liquid solution, the sporidia usually soon fall off from the promycelium, but continue to multiply by the yeast fashions of budding new sporidia, which soon separate and develop others, until the nourishment is exhausted. Then the sporidia may develop infection threads.

The second chief type of germination is shown by the species of *Tilletiaceæ*, Fig. 22. The simple or septate promycelium in this case bears all of the elongated sporidia in a terminal cluster. Sometimes these primary sporidia develop terminal secondary sporidia. With some species the sporidia, before or after falling off from the promycelium, become yoked in pairs by short connecting threads. In nutrient solutions some of the species develop finally a complicated mycelium that bears numerous aërial sporidia or conidia quite different from the normal type produced in water. The conidia develop infection threads on germination.

Infection of Host. The host is entered by the fine infection threads of the promycelia or the sporidia boring through its tissues into the interior. Once inside, these develop the mycelium of which we have already spoken. Many of the smuts infect their host only through the young hypocotyl or epicotyl of the seedling. In these cases the smut usually can not gain successful entrance after the plants appear above ground. Once inside, the mycelium rapidly penetrates the young tissues, seeking to gain access to the growing tip, where

it then follows the upward growth of the plant, often not giving evidence of its presence until it breaks out in its spore stage in the fruiting organs of the host two or three months later. This is the case with the oat smuts, wheat and barley smuts, and the grain smut of broom-corn. In this latter case the mycelium has traveled upward through six to ten feet of the cane. In other species infection may take place through any very young tissue of the host upon which the germs may be blown or washed into contact. This is the case with corn, and the corn smut appears soon after infection in its smutty outbreaks, the mycelium usually remaining localized. With the *Entylomas* the infection is largely confined to the leaves, and apparently the mycelium is limited to the vicinity of the sorus.

ECONOMIC IMPORTANCE.

Injury. While most of the smuts occur on plants of no economic importance, there are at least twenty-five species in America that do more or less injury to cultivated plants. Some of these cause such serious injury that they are counted among the worst species of parasitic fungi. It is with the cereals that the smuts do most damage. Wheat, oats, barley, rye, and corn are all subject to attacks from one or more species. With the first three hosts the smuts break out in the inflorescence, entirely preventing the formation of the seed. It thus becomes an easy matter to determine rather accurately the per cent. of loss in fields of these grains by counting the number of smutted and of free heads in a given area. Oat smut, for instance, in our central states generally claims from one to fifteen per cent. of the grain, and in some few fields as high as thirty or forty per cent. has been destroyed. In Illinois there is perhaps an average loss per year of one million dollars worth of oats, caused by the two smuts of this plant. In Indiana Arthur found one field of wheat where fifty per cent. of the grain was destroyed by the stinking smut. In the northwestern states, in the wheat districts, the loss caused by this latter smut is very great, as it is one of their worst fungous pests. When abundant it renders the grain inferior for milling purposes, as the spores may be so numerous in the flour that they darken

it. In South Carolina during recent years a smut of rice has been introduced from Japan, and causes some loss to this crop. In the eastern states where onions are raised extensively, the onion smut often does considerable injury. In this case the smut becomes established in the soil and often prevents profitable onion culture on this land. Corn smut is common everywhere, and especially on sweet corn causes considerable injury. In Connecticut the most injurious smuts, from an economic standpoint, are those of onion, corn, barley, and oats.

Prevention. With those plants where infection takes place through the germinating seed, the danger usually comes from the spores that mechanically adhere to the seed. It has been found that, if these are killed, the crop from this seed will be free from smut. Investigations have shown that certain treatment of the grain with chemical solutions or with hot water will kill the spores with little or no injury to the seed. For instance, it has long been known that soaking the seed of wheat in a solution of copper sulphate of a certain strength for a certain time serves to prevent or lessen the amount of stinking smut in the crop. Later it was found that soaking the seed for ten or fifteen minutes in hot water at a temperature of 132° to 135° F. was a more efficient remedy, since there was less likelihood of injury to the seed. More recently still came the less cumbersome practice of sprinkling piles of the grain with formalin, one pint to fifty gallons of water, stirring the grain to thoroughly wet it, and leaving it in piles or in bags over night for the fumes to act on the spores. The smuts of oats, the covered smut of barley, the stinking smut of wheat, the grain smut of sorghum and broom-corn, and the grain smut of millet, have all yielded to seed treatment. The loose smuts of wheat and barley can be prevented or lessened by a severer method of the hot water treatment (in which a preliminary soaking of several hours in cold water precedes the hot water treatment), but this also injures the seed more or less, so that a greater quantity per acre must be sown. Corn smut can not be prevented by seed treatment, as the smut gains entrance through any young tissue of the host. Some experimenters have advocated the removal of the smut-balls as soon as they appear. It is known that the fungus develops aërial conidia

in manure, and so fresh manure applied to corn land is apt to increase the amount of smut. With onion smut we have a case where the seedlings while coming through the soil are infected by the smut established there through a previous smutted crop. Onions raised from sets in this land are little infected. Some success has been had in preventing this smut by treating the soil with a mixture of lime and sulphur, drilled into it at time of seeding.

SYSTEMATIC TREATMENT OF CONNECTICUT SPECIES.

The order *Ustilagineæ* is divided into two families, based chiefly on the method of spore germination. They are the *Ustilaginaceæ* (represented in this state by the genera *Cintractia, Schizonella, Sorosporium, Sphacelotheca, Tolyposporium, Ustilago*), and the *Tilletiaceæ* (represented by *Doassansia, Entyloma, Neovossia, Tilletia, Tracya, Urocystis*).

Key to Genera.

I. Spores simple.
- A. Usually forming a dusty sorus at maturity (see also IB and IIIA1a).
  - 1. Large, usually 16-35μ.
    - a. With an elongated hyaline appendage..... *Neovossia.*
    - b. Without a conspicuous appendage. *Tilletia.*
  - 2. Small to medium, usually 5-18μ.
    - a. Sorus covered with a false membrane of definite fungous cells..... *Sphacelotheca.*
    - b. Protecting membrane of plant tissue only (sometimes with gelatinized hyphæ)...... *Ustilago.*
- B. More or less firmly agglutinated at maturity....... *Cintractia.*
- C. Permanently imbedded in leaves, producing discolored areas .... *Entyloma.*

II. Spores chiefly in pairs, forming an agglutinated sorus... *Schizonella.*

III. Spores in more or less permanent balls.
  A. Forming a dusty or granular sorus at maturity.
    1. Spore balls consisting only of spores.
      a. Often evanescent (Ustilago-like spores)... *Sorosporium.*
      b. Quite permanent, adhering by folds of spore coats ....*Tolyposporium.*
    2. Spore balls with a cortex of sterile cells...... *Urocystis.*
  B. Permanently embedded in the plant tissues.
    1. Spore balls with a definite cortex of sterile cells *Doassansia.*
    2. Spore balls without cortex but with sterile threads in center ....*Tracya.*

USTILAGINACEÆ Schröt.

The sori usually form exposed, dusty, or agglutinated spore masses. Germination is by means of a septate promycelium, which usually gives rise to terminal and lateral sporidia (capable of yeast-like multiplication in nutrient solutions), or else to infection threads. Figs. 21, 23-25.

Ustilago Rouss.

The sori occur on various parts of the host, according to the species, and at maturity form dusty, usually dark colored spore masses. The spores are single, separate, of small to medium size (5-18μ), and are produced irregularly in fertile threads that entirely disappear through gelatinization at maturity. Figs. 1-4, 43-55.

This is the most common and the typical genus of the smuts. Saccardo, in his *Sylloge Fungorum,* describes about 250 species for the world: 72 species occur in North America and 18 in Connecticut. A number of the species possess economic importance as parasites of the cereals.

Key to Species of Ustilago.

I. Spores olive or reddish brown.
  A. Spores smooth.
    1. Sori in leaves forming linear striæ.......... *U. longissima.*

2. Sori in spikelets, ovoid.
   a. Spores usually lighter colored on one side, 5-9μ.
      * Spikelets entirely destroyed... *U. Hordei.*
      ** Spikelets smutted only at base.. *U. levis.*
   b. Spores uniformly colored, 8-11μ.......... *U. Crameri.*

B. Spores echinulate or verruculose.
1. Sorus in each spikelet, distinct.
   a. Spores usually lighter colored on one side, 5-9μ.
      * Host *Arrhenatherum avenaceum* (Oat Grass) .... *U. perennans.*
      ** Host *Avena sativa* (Oats)... *U. Avenæ.*
      *** Host *Hordeum vulgare* (Barley)..... *U. nuda.*
   b. Spores uniformly colored, 10-14μ......... *U. Panici-glauci.*
2. Sorus involving the entire panicle............ *U. Rabenhorstiana.*
3. Sori in the ovaries.
   a. Smooth and inconspicuous, 1-2 mm.
      * Spores echinulate ...... *U. spermophora.*
      ** Spores verruculose .... *U. Eriocauli.*
   b. Hispid and conspicuous, 4-10 mm........ *U. sphærogena.*
4. Sori in leaves (rarely on stem).
   a. Forming nodular swellings, often at nodes *U. Crus-galli.*
   b. Forming linear striæ in the blades........ *U. striæformis.*
5. Sori breaking out on any part of host, often large .... *U. Zeæ.*

II. Spores golden brown, verrucose; sori in seeds......... *U. Oxalidis.*

III. Spores violet or purplish, reticulate, sori in flowers.
1. Reticulations rather fine, 1-3μ.... *U. anomala.*
2. Reticulations rather coarse, 2-4μ. *U. utriculosa.*

Ustilago longissima (Sow.) Tul. Fig. 1. The sori form more or less distinct, linear striæ from a few mm. to length of leaf; the epidermal covering soon ruptures, and the dark reddish brown spore mass becomes scattered from the more or less shredded tissues. The spores are light brown, oblong, or more commonly ellipsoidal to spherical, smooth (or sometimes scarcely granular under an immersion lens), 4-8μ in length.

Host and Distr.: *Glyceria grandis*, Shaker Station, June 29, 1903.

This species undoubtedly has a wider distribution than indicated above.

Ustilago Hordei (Pers.) Kell. & Sw. Fig. 46. The sori occur in every spikelet, forming an ovate, adhering, purple-black spore mass, 6-10 mm. in length, and rather permanently covered by the thin, usually transparent plant tissue. The spores are reddish brown, slightly lighter colored on one side, chiefly subspherical or spherical, smooth, and 5-9μ, rarely (most elongated) 9-11μ, in length.

Host and Distr.: *Hordeum vulgare*, Whitneyville, Sept. 24, 1902.

This covered smut of barley is not nearly so common in this state as is the loose smut of the same host.

Ustilago levis (Kell. & Sw.) Magn. Fig. 45. The sori usually occur in all of the spikelets, are more or less hidden by the enveloping glumes (which may be infected only at their base or in the interior), and form rather permanent, black-brown, semi-agglutinated, ovate spore masses 6-10 mm. in length. The spores are reddish brown, slightly lighter colored on one side, chiefly subspherical or spherical, smooth, 5-9μ, rarely (most elongated) 11μ, in length.

Host and Distr.: *Avena sativa*, New Haven, July 10, July 28, 1902.

This hidden smut of oats is not so common in our oat fields as is the loose smut, *U. Avenæ*.

Ustilago Crameri Körn. Fig. 44. The sori occur in all of the spikelets of the spike, destroying especially the inner and basal parts, and form ovate dusty brown spore masses 2-4 mm. in length. The spores are reddish brown, ovoid to

subspherical, or occasionally more elongated or irregular, smooth, often with pitted contents, and 8-11μ in length.

Host and Distr.: *Setaria Italica,* New Haven, Sept. 11, 1903.

So far this species has been found in this state only once, in a small plot of Hungarian grass grown at the Experiment Station. In some of the central and western states it sometimes causes considerable injury to its host. It can be prevented by seed treatment with hot water, formalin, etc.

Ustilago perennans Rostr. The sori occupy all of the spikelets, usually destroying the basal and inner parts (sometimes even running down slightly on the pedicles); they are oblong, 3-8 mm. in length, and have a somewhat protected semi-dusty olive brown spore mass. The spores are chiefly subspherical or spherical, occasionally ellipsoidal to ovate, usually lighter colored on one side, minutely echinulate, especially on lighter side, and 5-8μ in length.

Host and Distr.: *Arrhenatherum avenaceum,* South Manchester (Thaxter).

This is closely related to the oat smuts. Its mycelium becomes perennial in the underground parts of the host, and so smuts the infested plants year after year.

Ustilago Avenæ (Pers.) Jens. Figs. 23, 43. The sori appear in all of the spikelets, completely destroying all the floral parts, except a very temporary transparent covering membrane; eventually the olive brown dusty spore mass becomes dissipated, leaving behind only the naked pedicles. The spores are reddish brown, lighter colored on one side, subspherical to spherical, or occasionally more elongated, minutely echinulate, especially on the lighter side, and chiefly 5-9μ in length.

Host and Distr.: *Avena sativa,* New Haven, July 8, July 28, Aug. 17, 1902, Aug. 9, 1903; West Cornwall, July 18, 1902; Westville, July 7, 1903; West Haven, July 22, 1903.

This is a common pest in the oat fields of the state, though the per cent. of infected plants is smaller than in the central and western states. It yields to seed treatment.

Ustilago nuda (Jens.) Kell. & Sw. Fig. 47. The sori infest all of the spikelets, changing each into an olive brown,

oblong, dusty spore mass about 6-10 mm. in length; this is very temporarily protected by a thin transparent membrane, and upon dispersal of the spores nothing remains but the naked rhachis. The spores are lighter colored on one side, subspherical to spherical, or occasionally more elongated, minutely echinulate, especially on the lighter side, and chiefly 5-9μ in length.

Host and Distr.: *Hordeum vulgare,* Storrs, 1901; New Haven, July 8, 1902, June 15, 1904; Whitneyville, Sept. 24, 1902; Westville, July 7, 1903.

This is the loose smut of barley, and is rather common in the fields of this crop. The smuts of barley, oats, and oat grass, as will be seen by the descriptions, are very similar, in fact were not long ago considered one species. It requires the modified form of the hot-water treatment to prevent the loose smut of barley.

Ustilago Panici-glauci (Wallr.) Wint. Fig. 49. The sori occur in all of the spikelets, are ovate, 2-3 mm. in length, and at first protected by thin transparent glumes, but soon rupture these, and scatter the dusty black-brown spore mass. The spores are dark reddish brown, ovoid, spherical or sometimes more elongated, prominently and abundantly echinulate, and 10-14μ in length.

Host and Distr.: *Setaria glauca,* Southington, Aug. 8, 1902; Bridgeport, Sept. 15, 1902; Berlin, Oct. 3, 1902; Glastonbury, Oct. 23, 1902; Andover, Sept. 15, 1903; New Canaan, Sept. 29, 1903; Manchester, Oct. 2, 1903.

Throughout the United States this is a common smut on the yellow fox-tail grass, though it does not occur on the green fox-tail.

Ustilago Rabenhorstiana Kühn. Fig. 50. The sorus involves the entire inflorescence, changing it into a linear or oblong body, 3-5 cm. in length, which is usually hidden by the enveloping leaf sheath; it is covered for a short time by a very fragile transparent plant membrane, and within the dusty brown-black spore mass are often elongated remains of the plant tissues. The spores are reddish or olive brown, ovoid to spherical, or occasionally slightly angled, echinulate to verruculose, and 10-14μ in length.

Host and Distr.: *Panicum sanguinale,* Centreville, Aug. 10, Sept. 1, 1902; Unionville, Aug. 26, 1902; New Haven, Sept., 1902, Oct. 5, 1904; Westville, Aug. 25, 1903; Montowese, Sept. 14, 1903; New Canaan, Sept. 29, 1903.

This is one of the common grass smuts here as elsewhere, and is to be looked for in the fall of the year.

Ustilago spermophora B. & C. Fig. 52. The brown-black dusty sori occur in the ovaries, infesting one here and there; they show as small ovate bodies, about 2 mm. in length, extending between the spreading glumes, and are at first protected by a thin ovary membrane at the apex of which are the remains of the styles. The spores are light brown, ovoid to subspherical, usually prominently echinulate, and 8-11μ, or occasionally 13μ in length.

Host and Distr.: *Eragrostis major,* New Haven, Oct. 31, 1902; Westville, Oct. 17, 1903.

The sori usually occur in only a few of the ovaries, and are so inconspicuous that the smut is easily overlooked. Fig. 52 shows isolated spikelets of the grass with a single sorus in each.

Ustilago Eriocauli (Mass.) Clint. The sori occur in the ovaries, scarcely showing between the glumes as slightly swollen ovoid bodies about 1 mm. in length; a thin membrane protects the rather firm, at first semi-agglutinated, but finally dusty, olive-black spore mass. The spores are polyhedral, subspherical, or occasionally more elongated, rather prominently verruculose, and 9-15μ in length.

Host and Distr.: *Eriocaulon septangulare,* Whitneyville, Sept. 21, 1902.

It requires very close examination to detect the flower heads containing this inconspicuous smut, since they resemble the normal ones. The smut should be searched for in the fall.

Ustilago sphærogena Burr. Fig. 53. The sori occupy the ovaries, forming ovate bodies, 4-10 mm. in length, which are covered by a tough hispid plant membrane that ruptures irregularly from the apex, disclosing at first an agglutinated, but finally a dusty, olive brown spore mass. The spores are ovoid to subspherical, prominently and sharply echinulate, and 9-12μ in length.

Host and Distr.: *Panicum Crus-galli,* Conn. (Setchell); Savin Rock, Sept. 14, 1902; Westville, Sept. 12, 1902.

This species and the next are very closely related, and occur on the same host, but are rarely, if ever, found together. Fig. 53 shows a portion of the flower panicle with a single unusually large sorus.

Ustilago Crus-galli Tr. & Earle. The sori form nodules often encircling the leaf node, or more rarely occur in place of inflorescence, infecting both leaves and stem; they are one to several cm. in diameter and protected by a tough hispid plant membrane, which on rupture discloses an olive brown spore mass. The spores are reddish brown, ovoid to spherical, occasionally more elongated, rather bluntly echinulate or even verruculose, and 10-14μ in length.

Host and Distr.: *Panicum Crus-galli,* New Haven, Sept. 11, 1903.

Only a single specimen of this smut was found on a cultivated variety of this barn-yard grass grown at the Experiment Station.

Ustilago striæformis (West.) Niessl. Fig. 51. The sori occur in the leaves, rarely in the inflorescence, forming short linear striæ, or by terminal fusion reaching several cm. in length, and laterally are often so crowded as to cover most of the leaf; at first they are covered by the epidermis, but this soon ruptures, and the dusty brown-black spore masses become scattered from the shredded tissues. The spores are reddish brown, vary from ellipsoidal to spherical, or occasionally irregular, are prominently echinulate, and 9-14μ in length.

Hosts and Distr.: *Agrostis alba* var. *vulgaris,* Whitneyville, July 20, 1902, May 9, 1903; Centreville, June 12, 1904; *Phleum pratense,* Whitneyville, May 9, 1903; New Haven, May 16, 1903.

Both of these hosts are economic plants grown for pasture or hay, but so far the smut has been found on them in this state only in door yards. Fig. 51 shows the leaves of *Agrostis alba* var. *vulgaris* shredded by this fungus.

Ustilago Zeæ (Beckm.) Ung. Figs. 2, 55. The sori break out on any part of the host, often forming prominent smut balls, though these vary from a few mm. to over a dcm.

in diameter, and also vary in shape according to the part attacked; the brownish black spore mass is at first covered with a whitish membrane, composed largely of semi-gelatinized fungous threads. The spores are ellipsoidal to spherical, occasionally irregular, prominently echinulate, and 8-11μ, rarely even 15μ, in length.

Hosts and Distr.: *Euchlæna luxurians,* New Haven, Sept. 11, 1903; *Zea Mays,* New Haven (Sturgis), Aug. 18, 1901 (Rorer); Southington, July 17, 1902; Westville, Aug. 14, Sept. 2, 1902, June 28, 1904; Hartford, Oct. 20, 1902; New Canaan, Sept. 29, 1903.

Corn smut is common on both the sweet and field varieties, though in this state the former is more subject to its attacks. Seed treatment will not prevent the smut, as it can gain entrance to its host through any exposed young tissue. The first host given is teosinte, a plant that is closely related to corn. Fig. 55 shows smutted staminate blossoms of corn reduced to one-half size.

Ustilago Oxalidis Ell. & Tr. Figs. 3, 48. The inconspicuous sori are found in the seeds, all or part of these being changed into reddish brown dusty spore masses, that show to the exterior only on the dehiscence of the otherwise little modified ovaries. The spores are golden yellow, ovoid to spherical, or rarely more elongated or irregular, coarsely verrucose, and 13-20μ in length.

Host and Distr.: *Oxalis stricta,* Yalesville, July, 1902; West Cornwall, July 18, 1902; New Haven, July, 1902; Whitneyville, Oct. 18, 1902, Sept. 9, 1903; Manchester, Oct. 2, 1903.

An inconspicuous conidial stage is also produced on the surface of the anthers of the infected flowers. These temporary spores are thin-walled and ovoid to subspherical. They are so placed that they are probably carried from the flowers by insects, as are pollen grains. Fig. 48 shows two ovaries in which all of the seeds have been changed into smutty bodies.

Ustilago anomala Kze. The sori occur in the essential organs of all the flowers, the floral envelopes forming a covering to the dusty, purplish spore mass. The spores are light violet, ovoid to spherical, occasionally somewhat irregular, provided with rather fine winged reticulations (1-3μ wide by 1μ deep), and 10-15μ, rarely 17μ, in length.

Hosts and Distr.: *Polygonum Convolvulus* (?), Mt. Carmel, May 8, 1904 (last year's flowers); *Polygonum dumetorum* var. *scandens,* Montowese, Sept. 14, 1903; New Canaan, Sept. 29, 1903.

This species is closely related to the next, but differs in having usually lighter colored and somewhat larger spores, with finer reticulations.

Ustilago utriculosa (Nees.) Tul. Figs. 4, 21, 54. The sori destroy the essential organs of all of the flowers, and form ovate, dusty, purplish spore masses 3-4 mm. in length, protected at first by the floral envelopes. The spores are violet or purplish, chiefly subspherical or spherical, provided with rather coarse, winged reticulations (2-4μ wide by about 1.5μ deep), and chiefly 9-14μ in diameter.

Hosts and Distr.: *Polygonum Hydropiper,* Montowese, Sept. 20, 1902; *Polygonum hydropiperoides,* Whitneyville, July 24, 1902; *Polygonum lapathifolium,* Westville, Sept. 2, 1902; *Polygonum Pennsylvanicum,* Westville, Sept. 2, 1902; Hamden, Sept. 11, 1902; Hartford, Oct. 20, 1902; Glastonbury, Oct. 23, 1902; Yalesville, Sept. 11, 1903, Oct. 14, 1904; Montowese, Sept. 14, 1903; New Canaan, Sept. 29, 1903; Manchester, Oct. 2, 1903; Green's Farms, Sept. 30, 1904.

This is one of the most common smuts of the state, especially on the last host.

Sphacelotheca DeBy.

The sori are usually found in the inflorescence (often confined to the ovaries), are provided with a false membrane of fungous cells that soon ruptures, disclosing a dusty spore mass and a central columella composed chiefly of plant tissues. The false membrane is formed largely or entirely of definite sterile fungous cells which are hyaline or slightly tinted, and vary in shape from linear to subspherical or cuboidal, and in size from less than to larger than the spores. The spores are like those of *Ustilago,* simple, free, usually reddish brown, and of small to medium size. Figs. 5, 6, 37, 38.

Very often groups of the sterile subspherical cells are scattered through the spore mass. The columella is usually the remains of the woody plant tissues, and often protrudes above

the spore mass as the latter wears away. See Fig. 37. This genus has not been thoroughly worked up for the whole world, and so a number of the species belonging under it are now included under *Ustilago*. Only two of the 16 species occurring in North America are of economic importance. So far only two species have been found in Connecticut.

Key to Species of Sphacelotheca.

I. Spores olive brown, smooth................*S. Sorghi.*
II. Spores purplish, verruculose..........*S. Hydropiperis.*

Sphacelotheca Sorghi (Lk.) Clint. Figs. 5, 24, 26, 38. The sori occur in the ovaries, forming oblong or ovate bodies usually 3-8 mm. in length, or rarely fusing the aborted spikelets into longer forms. The brownish false membrane wears away from the apex, revealing the olive brown spore mass and finally the evident slender columella. The sterile cells of the membrane easily break up into groups, and are hyaline, oblong to subspherical, and chiefly 7-18μ in length. The olive brown spores are subspherical or spherical, smooth, often have pitted contents, and are 5.5-8.5μ in diameter.

Hosts and Distr.: *Sorghum vulgare* var. *sorghum,* New Haven, Sept. 30, 1903; *Sorghum vulgare* var. *technicum,* New Haven, Sept. 20, 1901 (Rorer), Sept. 11, 1903.

This species was found on both sorghum and broom-corn grown at the Experiment Station. So far as I can learn, neither of these plants is grown commercially in the state, so the smut is of no economic importance here, though further west it often does considerable injury to these plants.

Sphacelotheca Hydropiperis (Schum.) DeBy. Figs. 6, 37. The sori are found in the ovaries, forming oblong or ovate bodies 3-5 mm. in length; with the false membrane dehiscing at the apex, and revealing the purple-black spore mass and finally the slender columella. The sterile cells, besides forming the false membrane, constitute part of the columella; they easily separate, are hyaline or slightly violet tinted, chiefly subspherical, and 6-17μ in length. The spores are purplish, broadly oblong or ovate to (chiefly) subspherical, very minutely but abundantly verruculose and 10-17μ in length.

Hosts and Distr.: *Polygonum acre,* Green's Farms, Sept.

30, 1904; *Polygonum sagittatum*, Westville, Sept. 2, 1902, Sept. 14, 1903 (Britton), Oct. 4, 1904; Montowese, Sept. 20, 1902; Whitneyville, Sept. 21, 1902; Centreville, Sept. 27, 1902; New Canaan, Oct. 9, 1902 (Britton), Sept. 11, 1903; Yalesville, Sept. 11, 1903; Andover, Sept. 15, 1903; Cheshire, Oct. 25, 1903.

This is another of the common smuts of the state, especially on the arrow-leaf Polygonum, and is found in the fall. It is the only purple-spored species of the genus, of which it is the type, however. Fig. 37 shows the smut on *Polygonum acre*, several of the sori exposing the slender central columella.

Cintractia Cornu.

The sori occur on various parts of the host, but most commonly in the ovaries; at maturity they form a firmly agglutinated, or more rarely a dusty, spore mass, which usually is protected at first by a false membrane of sterile threads or indefinite cells. The single spores develop centripetally around a central axis, the outermost wearing off as they ripen; they are usually of medium to large size, and of a dark reddish black color, often opaque. Figs. 8, 27, 28.

The species of this genus occur on the Cyperaceæ, or occasionally on related families. So far 17 species have been described, 13 occurring in North America, and 4 in Connecticut. None of the species are of economic importance.

Key to Species of Cintractia.

I. Sori dusty at maturity, concealed by the glumes.
  A. Spores usually irregular polyhedral......*C. Cyperi.*
  B. Spores usually ovoid to spherical (often with hyaline wings) ....*C. Montagnei.*
II. Sori firmly agglutinated at maturity.
  A. Subspherical, in ovaries................*C. Caricis.*
  B. Oblong to linear, surrounding base of pedicles..... *C. Junci.*

Cintractia Cyperi Clint. The sori occur in the interior of the spikelets, infecting all of the head, and are hidden by the enveloping glumes until finally the dusty spore mass sheds

out on their exterior. The spores are reddish brown, oblong to polyhedral, chiefly irregular, smooth, but often showing darker lines on surface due to pressure of spore mass, and 12-18μ, or (most elongated) even 22μ, in length.

Host and Distr.: *Cyperus filiculmis,* North Haven, July 26, 1902; Montowese, Sept. 14, 1903.

This species was described originally from this state by the writer, having been found not uncommon on the sand plains near North Haven and Montowese. The affected plants look very much like those free from the smut, but can usually be detected by the darker aspect of the spikelets, which in this sedge are clustered into heads.

Cintractia Montagnei (Tul.) Magn. The sori occur hidden in the ovaries, forming inconspicuous, oblong to subspherical, usually dusty spore masses. The spores are brown or brownish black, often compressed laterally, and so appearing ovoid to subspherical or occasionally more irregular and angled, smooth but minutely pitted, and 12-19μ, chiefly 13-16μ, in length; they are very often provided with conspicuous, hyaline, wing-like bladders on either side.

Host and Distr.: *Rhynchospora alba,* Berlin, Sept. 3, 1902; Cheshire, Oct. 25, 1903.

This is another smut readily overlooked, because the inconspicuous sori are hidden by the floral bracts.

Cintractia Caricis (Pers.) Magn. Figs. 8, 27. The sori form subspherical bodies about 3-4 mm. in diameter in the ovaries; at first the sorus is protected by a white membrane of sterile fungous tissue, but this soon wears off, revealing the black, firmly agglutinated spore mass, the spores of which gradually ripen and wear off toward the interior. The spores are black-brown, subopaque, chiefly irregular polyhedral, or occasionally ovoid to subspherical, smooth or pitted to granular or even papillate, and 16-27μ, chiefly 18-22μ, in length.

Host and Distr.: *Carex Pennsylvanica,* Rainbow, June 6, 1903; East Hartford, June 1, 1904 (Weatherby).

This variable smut has been reported on a large number of *Carex* species in North America, but the above is the one upon which it commonly occurs. The illustration shows it in the ovaries at the base of the staminate spikelet of this host.

Cintractia Junci (Schw.) Trel. Fig. 28. The sori are linear, usually surrounding the pedicles or peduncles for half or more of their lower length, occasionally developing in the basal parts of the flowers; they form a black, rather firmly agglutinated spore mass. The spores are black-brown, subopaque, oblong to irregular polyhedral or subspherical, very minutely pitted, and 14-22μ in length.

Host and Distr.: *Juncus tenuis,* Westville, June, 1891 (Thaxter); Milford, June 26, 1894 (Sturgis), July 27, 1902; Whitneyville, June 20, 1902.

This was one of the first smuts reported from North America, having been described by Schweinitz from Carolina in 1834. The figure shows one of the peduncles smutted for half its length.

Schizonella Schröt.

The sori form black agglutinated spore masses in the leaves. The spores are united in pairs (formed by internal division of a mother cell), and often become laxly connected by their bulging contiguous surfaces, or even entirely separated; they are of reddish brown color and of small or medium size. Figs. 9, 35.

Only one species, with a variety, is known for this genus, but it has a wide distribution on various species of *Carex.* In North America it has been found chiefly on *Carex Pennsylvanica,* its host in this state.

Schizonella melanogramma (DC.) Schröt. Figs. 9, 35. The sori form black, agglutinated, linear, elevated striæ, 1 or 2 mm. long, or, by terminal fusion, of considerable length, chiefly on the upper sides of the leaves. The spores are dark reddish brown, often with the cells entirely or partially separated by the bulging out of their contiguous surfaces, chiefly ellipsoidal to hemispherical, or, when separated entirely, polyhedral or subspherical, and 8-12μ in length.

Host and Distr.: *Carex Pennsylvanica,* Westville, July 12, 1902; Whitneyville, May 4, 1903.

This is a species found chiefly in the spring; it probably has a much wider distribution than indicated here.

Sorosporium Rud.

The sori occur in various parts of the host, forming dusty dark colored spore masses like *Ustilago*. The medium-sized spore balls are composed of numerous spores, often so loosely held together that in time they separate entirely. The spores are like those of *Ustilago*, simple, olive to reddish brown, and of medium size. Figs. 7, 36.

When the spore balls become separated into the individual spores, it is difficult to distinguish the species from *Ustilago*. The number of species described by Saccardo is over 30, but some of these probably belong under other genera. For North America 9 species are now known, and 2 or 3 of these occur in Connecticut.

Key to Species of Sorosporium.

I. Sori in ovaries, 1-2 cm. in length; spores 8-12μ........ *S. Everhartii.*

II. Sori involving the entire infloresence usually.

  A. Sorus 1-5 cm.; spores 12-19μ..........*S. Ellisii.*

  B. Sorus usually 3-7 cm.; spores 9-13μ............. *S. Syntherismæ.*

Sorosporium Everhartii Ell. & Gall. The sori develop in the ovaries, forming linear bodies 1-2 cm. in length, and are covered with a prominent whitish false membrane that dehisces at the apex into several lobes, disclosing the black-brown, semi-agglutinated spore mass and the flattened columella of plant tissue. The spore balls are oblong to subspherical, composed of many firmly agglutinated spores, and vary from 55 to 125μ in length. The spores are reddish brown, or the interior ones often nearly hyaline, ovoid to subspherical or polyhedral, smooth (outermost rarely granular), and 8-12μ in length.

Host and Distr.: *Andropogon scoparius*, Westville, Oct. 22, 1903; [Southington, July 16, 1902; North Haven, July 26, 1902; Montowese, Sept. 20, 1902; New Haven, Oct. 18, 1903].

The first specimen mentioned above is typical of the species as described here. Those included in the brackets were origi-

nally considered by the writer as belonging under *S. Ellisii,* since their sori involve the entire inflorescence, instead of being limited to the ovaries. The spores, however, are smaller than those of the typical members of that species, and both the spores and spore balls are like *S. Everhartii,* so they may possibly be only vigorous specimens of this species, in which the sorus has involved the whole inflorescence.

Sorosporium Syntherismæ (Pk.) Farl. Figs. 7, 36. The elongated sori usually involve the entire inflorescence, 3-7 cm. in length, or more rarely are limited to the individual spikelets, when they are shorter; they are provided with a prominent false membrane which ruptures irregularly, disclosing the black-brown spore mass, within which are often shredded filaments of plant tissues. The sterile cells of the membrane are hyaline, oblong to cubical or subspherical, and tend to adhere in filaments when crushed apart. The spore balls, often evanescent when old, are irregular oblong to subspherical, and 40-100μ in length. The reddish brown spores are minutely verrucose (the inner often smooth and more lightly colored), subspherical, polyhedral or occasionally more elongated, chiefly 9-13μ in length.

Host and Distr.: *Cenchrus tribuloides,* Savin Rock, Aug. 30, 1902; Montowese, Sept. 20, 1902.

This species should also be looked for on *Panicum proliferum,* which is a common host for it elsewhere.

Tolyposporium Wor.

The sori are usually found in the ovaries, forming a granular spore mass at maturity. The spore balls are of medium size, dark colored, and composed of numerous permanently united spores. The spores are bound together by ridged folds or thickenings of their outer walls, and are of small to medium size. Figs. 10, 40.

The spore balls can be ruptured by pressure, when the outer darker colored covering often breaks apart as ridges or spine-like projections on the light colored or hyaline spores. So far 13 species have been described, though it is doubtful if all belong to this genus; 2 of these occur in North America,

and 1 in Connecticut. None of the species apparently are of economic importance.

Tolyposporium bullatum (Schröt) Schröt. Figs. 10, 40. The ovate sori are found in the ovaries, are about 3-5 mm. in length, and are covered by a smooth greenish plant membrane, which upon rupturing discloses the granular, black spore mass. The spore balls are opaque, black, oblong to spherical or polyhedral, contain numerous (over 100) firmly agglutinated spores, and are 50-160μ in length. The spores are light reddish brown, or the inner ones semi-hyaline, and are covered with a thin, tinted outer coat thrown more or less into ridges or folds that bind the spores together; they vary from ovoid to spherical or polyhedral, and are 7-12μ, rarely 14μ, in length.

Host and Distr.: *Panicum Crus-galli*, Woodmont (Setchell); Unionville, Aug. 26, 1902; New Haven, Sept. 11, 1903; New Canaan, Sept. 29, 1903.

Sometimes *Ustilago sphærogena* occurs in the ovaries of the same plant with this. It can easily be distinguished from this by its larger sori, which are covered by a *hispid* membrane. Figure 40 shows the uppermost ovary only infected by the fungus.

TILLETIACEÆ Schröt.

The sori form dusty erumpent spore masses, or are permanently embedded in the plant tissues, often without evident distortion of these. The germination is by means of a promycelium, which usually gives rise to a terminal cluster of elongated sporidia, which sometimes bear whorls of similar secondary sporidia; or the primary sporidia, with or without fusing in pairs, may give rise to infection threads, or in a nutrient medium to a mycelium bearing dissimilar secondary sporidia (aerial conidia). Fig. 22.

Tilletia Tul.

The sori occur in various parts of the host, usually in the ovaries, forming a dusty, dark spore mass. The spores are simple, separate, and originate singly in the ends of special mycelial threads that generally disappear rather completely

through gelatinization; they are of large size, 16-35μ. Figs. 11, 12, 39.

This is the type of the family, and is one of the larger genera. The sorus is quite like that of *Ustilago,* but the spores are usually considerably larger. Saccardo records 53 species; 15 have been found in North America, but only 2 in Connecticut. The important stinking smuts of wheat, which cause so much damage in the western wheat districts, belong in this genus; but, as wheat is little grown in this state, neither species has been reported here. The smooth-spored species, *Tilletia fœtens* (B. & C.) Trel., however, has been found, on microscopic examination, in ground cattle food offered for sale in the state, apparently made from smutted western wheat. The cattle did not relish this food.

Key to Species of Tilletia.

I. Spores reticulate....................*T. Anthoxanthi.*
II. Spores apparently verruculose...........*T. Maclagani.*

Tilletia Anthoxanthi Blytt. Figs. 12, 39. The sori are ovate, about 3 mm. in length, and usually occur in all of the ovaries of the spike; they are somewhat hidden by the enveloping glumes, and at first are covered by a thin plant membrane, which eventually ruptures, disclosing the dusty, reddish black spore mass. Hyaline cells, or immature spores, are mixed with the spores, and are smaller than those, and have thin to medium-thick walls. The mature spores are reddish brown, ovoid to spherical, reticulate (3-6μ wide and 1-3μ deep), and 24-30μ, occasionally even 34μ, in length.

Host and Distr.: *Anthoxanthum odoratum,* Whitneyville, July 6, 1902.

The sori are so inconspicuous in the ovaries that the infected spikes scarcely differ in appearance from the normal. See Fig. 39, in which the spike is magnified two diameters. This European species has been found in this country only at the above station.

Tilletia Maclagani (Berk.) Clint. Fig. 11. The sori are found in the ovaries, and rarely also in the anthers, and are inconspicuous, being concealed by the enveloping glumes; upon

the rupture of the enclosing plant membrane, a dusty, reddish brown spore mass is disclosed. The spores usually show various stages of development, vary from light to dark reddish brown, are subspherical or spherical, or occasionally elongated or irregular, have a thick wall (3-4μ) apparently closely covered with verruculations (really very minutely areolately pitted), and are 18-27μ in length.

Host and Distr.: *Panicum virgatum,* Conn. (Herb. Farlow); East Hartford, July 7, 1903 (Weatherby).

The wild grass which is host for this smut is often cut for hay in the state, but it is doubtful if the smut does enough damage to be of economic importance.

Neovossia Körn.

The sori occur in the ovaries, forming dusty spore masses protected at first by a membrane of plant tissue. The large spores are simple, separate, and produced singly in the swollen ends of the special fertile hyphæ, which permanently invest them and taper into conspicuous elongated hyaline appendages. Fig. 13.

This genus is closely related to *Tilletia,* but can be distinguished by the tail-like appendage to the membrane investing the spores. There are only two species now known that properly come under this genus.

Neovossia Iowensis Hume & Hods. Fig. 13. The sori are found in the ovaries, are ovoid, about 2-3 mm. in length, and show inconspicuously between the spreading glumes. Sterile cells, or immature spores, which are hyaline, thick-walled, and chiefly smaller than the spores, are found in the spore mass. The mature spores are reddish brown, subopaque, ovoid, ellipsoidal, or rarely subspherical, provided with a hyaline envelope tapering into an irregular tail once or twice their length. They have a minutely reticulately pitted cell wall, and are 19-28μ by 13-19μ in size.

Host and Distr.: *Phragmites communis,* Montowese, fall, 1901 (Evans); Oct. 18, 1902.

This rare species, which has been reported elsewhere only from Iowa, was first found in this state by Professor Evans of Yale.

Urocystis Rab.

The sori usually occur in the leaves or stems, where they often cause considerable distortion, or more rarely in the floral parts, and form dark colored, dusty spore masses. The spore balls are permanent, composed of an enveloping cortex of tinted sterile cells, enclosing one to several spores, and are of small to medium size. The spores are reddish brown, and of variable shape and size. Figs. 14, 15, 41, 42.

The sori of this genus look very much like those of *Ustilago*. Saccardo in his *Sylloge Fungorum* describes 34 species; 12 of these occur in North America, and 4 have been listed from this state. A few of the species are of some economic importance.

Key to Species of Urocystis.

I. Spore balls usually with 1 fertile cell, rarely with 2; sori forming extended outbreaks on leaves and bulbs .... *U. Cepulæ.*

II. Spore balls usually with 1 or 2 fertile cells, rarely with 3 or 4.

   A. Sori forming pustular or irregular swellings on leaves and stem.............. *U. Anemones.*

   B. Sori in striæ usually on under side of leaf sheath .... *U. occulta.*

III. Spore balls usually with 3 to 5 fertile cells, rarely with more; sori oblong in base of flowers...... *U. Hypoxys.*

Urocystis Cepulæ Frost. Figs. 14, 42. The sori occur in the leaves and bulbs as isolated pustules or often as more extended areas, and are at first covered by a thin plant membrane, but eventually rupture this, disclosing a black, dusty spore mass. The spore balls are ovoid to spherical, small, 17-25μ in length, and contain one or rarely two spores. The sterile cells are tinted, ovoid to spherical, small, 4-8μ, and rather completely cover the spores. The spores are reddish brown, ovoid to spherical, and chiefly 12-16μ in length.

Host and Distr.: *Allium Cepa,* Green's Farms, June,

1890 (Thaxter), Oct. 22, 1902, June 24, 1904; Bridgeport, Sept., 1902; New Haven, June 23, 1904.

This is one of the most injurious smuts in this state. It occurs early in the season on the young seedlings, many of which may be killed outright, thus thinning out the stand irregularly. It is also found throughout the season, eventually doing considerable damage to the bulbs. The smut often becomes established in the soil, which is then rendered unfit for raising onions from seed. Sets, however, transplanted in the infected soil, suffer little from this trouble. Soil once infected remains so for years, and for this reason there is considerable land in the onion districts of the state that cannot be used to advantage for this crop. Experiments with treating the infected soil, at time of planting the seed, with various fungicides, such as formalin, and sulphur mixed with lime, have given some favorable results in keeping down the smut. As yet, however, such treatment is little practiced by the growers.

Urocystis Anemones (Pers.) Wint. The sori develop in the leaf blades, petioles, and stems, forming conspicuous pustules of varying shape and size, and soon disclose dusty, black spore masses. The spore balls are irregular, contain 1-5, usually 1-2 spores, and are 22-35μ, rarely 45μ, in length. The sterile cells usually incompletely cover the spores, and sometimes become separated from them; they are smoky brown or yellowish tinted, ovoid to spherical, and about 8-14μ in length. The spores are reddish brown, irregular, oblong or ovoid to polyhedral or subspherical, smooth, and chiefly 12-17μ, rarely 20μ, in length.

Host and Distr.: *Anemone nemorosa*, Milford, May, 1891 (Thaxter).

This smut is found early in the spring, and no doubt has a wider distribution and other hosts in the family Ranunculaceæ than that reported here.

Urocystis occulta (Wallr.) Rab. Figs. 15, 41. The sori of this smut are usually confined to the leaves, especially the inner side of the leaf sheaths, but occasionally occur in the culm or inflorescence; they form linear striæ of considerable length, and often are so closely placed that they merge into a dusty, reddish black stratum. The spore balls are ob-

long to subspherical, contain 1 or 2, rarely 3 or 4, spores, and are 16-32μ in length. The sterile cells usually incompletely cover the spores, are hyaline or yellowish tinted, and subspherical to oblong. The spores are reddish brown, oblong to subspherical, often irregularly flattened, smooth, and 11-18μ in length.

Host and Distr.: *Secale cereale,* Milford, June, 1890 (Thaxter); Rainbow, June 6, 1903.

The smut possesses some economic importance, since it occurs on cultivated rye. However, it apparently rarely becomes so abundant in the rye fields of this state as to cause serious injury. So far the writer has been able to find only a single smutted plant, though a number of fields have been examined.

Urocystis Hypoxyis Thaxt. The sori occur in the inner and basal parts of the flowers, distorting and destroying them more or less, and often run down somewhat on the pedicles; the infected parts have an irregular oblong shape, and finally disclose the dusty, purple-black spore mass. The spore balls vary from ovoid to spherical, contain 1-8, chiefly 3-5, spores, and are 25-60μ in length. The sterile cells completely cover the spores, are reddish yellow, ovoid, and 9-14μ in length. The spores are reddish brown, polyhedral, subspherical, or occasionally ovoid to oblong, and usually 13-16μ in length.

Host and Distr.: *Hypoxys erecta,* Westville, July, 1889 (Thaxter), July 12, 1902.

This smut was originally described from the specimens found by Professor Thaxter of Harvard in West Rock Park, Westville. Since then it has been reported from Massachusetts and South America.

Entyloma DeBy.

The sori occur chiefly in the leaves, being permanently embedded in their tissues, and forming discolored but usually scarcely distorted areas. The spores are hyaline or yellowish tinted, rarely darker colored, simple, separate, or occasionally slightly adhering together in rows or irregular masses, and of medium size. Elongated conidia are often produced from the

mycelium, protruding in tufts through the stomates. Figs. 16-18, 30-34.

About 70 species have been described, of which 25 occur in North America. Of the latter, four occur on cultivated hosts, but are not of especial economic importance. So far 8 species have been reported in Connecticut.

Key to Species of Entyloma.

I. Spores dark tinted, reddish brown, often adhering together.
  A. Sori forming minute, black, oblong or linear striæ.
    1. Spores golden brown, 7-11μ....... *E. lineatum.*
    2. Spores darker brown, 8-14μ... *E. crastophilum.*

II. Spores hyaline or yellowish tinted; sori forming discolored spots.
  A. Spores not apiculate, often adhering somewhat.
    1. With hypophyllous conidia or sporidia.
      a. Sori yellowish or reddish brown, 1-2 mm. *E. Thalictri.*
      b. Sori whitish or yellowish, 1-10 mm........ *E. Lobeliæ.*
      c. Sori yellowish or reddish, often bordered, ½-6 mm................. *E. Physalidis.*
    2. Usually without conidia.
      a. Sori light yellowish, ½-2 mm... *E. Linariæ.*
      b. Sori yellowish or reddish brown, 2-5 mm... *E. polysporum.*
  B. Spores apiculate and pedicellate, never adhering; sori yellowish, later reddish brown..... *E. Nymphææ.*

Entyloma lineatum (Cke.) Davis. Figs. 16, 32. The sori occur in the leaves, leaf sheaths, or occasionally in the culm, and are small, ½-3 mm. in length, subcircular to (chiefly) linear, scattered or fusing somewhat, lead-colored or black, and rather permanently covered by the epidermis. The spores are light golden brown, firmly agglutinated, usually ovoid to subspherical or somewhat polyhedral, smooth, and 7-11μ in length.

Host and Distr.: *Zizania aquatica,* New Haven, 1892 (Setchell); Whitneyville, July 24, 1902; Montowese, Oct. 18, 1902; Westville, Aug. 21, 1903.

Entyloma crastophilum Sacc. This species is closely related to the preceding, but differs in its slightly smaller sori and somewhat darker colored spores which are 8-14μ in length.

Host and Distr.: *Holcus lanatus,* West Haven, July 23, 1903; *Undetermined grass,* West Haven, Aug. 12, 1903.

Both this and the preceding species differ from the ordinary *Entylomas* in their darker colored spores.

Entyloma Thalictri Schröt. The sori are found in the leaves, forming small, angular, yellowish or reddish spots about 1-2 mm. in diameter, or by confluence becoming more extended and indefinite. The spores are hyaline or yellowish, ovoid to subspherical or occasionally somewhat angled and more irregular, thin-walled to medium thick-walled, smooth, and 8-13μ in length. The conidia are apparently produced on the under surface of the sori.

Host and Distr.: *Thalictrum polygamum,* Montowese, Sept. 14, 1903.

This species is not very common, and has been reported on the above host only from this state.

Entyloma Lobeliæ Farl. Figs. 17, 31. The sori form conspicuous whitish or yellowish areas in the leaves, and are 1-10 mm. in diameter. The spores are hyaline or yellowish tinted, oblong to subspherical or somewhat angled, rather thick-walled, and 11-15μ in length. The conidia form a whitish growth on the under surface of the sori, and are fusiform, and 10-25μ by 2-3μ in size.

Host and Distr.: *Lobelia inflata,* Hamden, Sept. 11, 1902; Hartford, Oct. 20, 1902; Cheshire, Aug. 3, 1903; Yalesville, Oct. 14, 1904.

This is probably the most common *Entyloma* occurring in the New England states, but so far it has been found only on the above species of Lobelia.

Entyloma Physalidis (K. & C.) Wint. Fig. 34. The sori form at first yellowish, but later darker colored, roundish or angular spots from ½-6 mm. in diameter. The spores vary from slightly tinted to light or reddish yellow, are ovoid, spher-

ical or slightly angled, have a thickish wall, and are 10-16μ in length. The conidia may occur on either surface of the sorus as a whitish growth, and are linear, somewhat curved, and 30-55μ by 1-2μ in size.

Host and Distr.: *Physalis pubescens,* South Manchester (Thaxter); New Haven, Sept. 16, 1902, Sept. 30, 1903; *Physalis Virginiana,* Hamden, Oct. 14, 1903.

The cultivated strawberry tomato, *Physalis pubescens,* is sometimes rather seriously injured by this smut. The figure shows the sori on this host, the spots having a definite darker border.

Entyloma Linariæ Schröt. Fig. 30. The sori show as small, faint, yellowish spots on the under surface of the leaves, and are oval to circular in outline, and ½-2 mm. in diameter. The hyaline or yellowish spores are chiefly subspherical or spherical, smooth, have evident double wall, and are 11-15μ, in length. The conidia have not been observed.

Host and Distr.: *Linaria vulgaris,* Westville, Oct. 22, 1903.

This species has been reported on this host only twice in North America. The variety is more common.

Entyloma Linariæ var. **Veronicæ** Wint. The sori are somewhat more evident than in the typical form of the species, showing on both sides of the leaf. The spores also are deeper tinted and larger, 13-16μ, or rarely 19μ, in length.

Host and Distr.: *Veronica peregrina,* New Haven, May 16, 1904.

Entyloma polysporum (Pk.) Farl. The sori form subcircular or more irregular, yellowish or (later) dark brown spots, 2-5 mm., in the leaves; the surrounding tissue is often killed, thereby merging the sori. The spores are usually hyaline to yellowish, or more rarely even chestnut brown, ovoid to spherical or somewhat polyhedral, smooth, provided with evident thick double wall, and chiefly 12-17μ in length. Conidia, apparently, are lacking.

Host and Distr.: *Ambrosia artemisiæfolia,* Cheshire, Aug. 3, 1903.

The closely related species *Entyloma Compositarum* Farl., also on Compositæ as hosts, probably also occurs in this state, though not yet reported.

Entyloma Nymphææ (Cunn.) Setch. Figs. 18, 33. The sori occur in the leaves, forming yellowish, or with age reddish brown, variable, usually irregular areas most prominent on the under surface. The hyaline spores are ovoid to subspherical, usually distinctly apiculate, and with remains of hypha as an appendage at opposite end, smooth or, under an immersion lens, very minutely verruculose, 10-14μ in length. Conidia have not been found, but the spores germinate *in situ.*

Hosts and Distr.: *Nuphar advena,* New Haven (Setchell); *Nymphæa odorata,* Ledyard (Setchell); Westville, Sept. 2, 1902, Oct. 3, 1904.

The appendaged and apiculate spores easily distinguish this species from any other. Fig. 33 shows the sori on a portion of the leaf of *Nymphæa odorata.*

Doassansia Cornu.

The sori occur on various parts of the host, usually in the leaves, and are rather permanently embedded in the tissues. The spores are united into large, permanent spore balls; these consist of a distinct cortical layer of sterile cells, with the spores entirely filling the interior, or limited to one or two layers beneath the cortex, while the interior is filled with sterile cells or threads. The spores are hyaline or yellowish tinted, smooth, and of small to medium size. Figs. 19, 22, 29.

Our knowledge of this and the next genus is largely due to the investigations of Professor Setchell of the University of California, but at one time a resident of this state, where he collected part of the material with which he worked. The species occur chiefly on plants growing in moist situations, especially on the Alismaceæ. Of the 24 species described, 10 occur in North America, and 5 in Connecticut. They are of no economic importance.

Key to Species of Doassansia.

I. Spore balls with spores entirely filling their interior; sori forming lead-colored, slightly elevated pustules in leaves.............................*D. opaca.*

II. Spore balls with a single layer of spores within which are sterile cells.

A. Sori in the slightly swollen ovaries.....*D. occulta.*
B. Sori forming discolored areas in leaves..........
D. Martianoffiana.
C. Sori forming conspicuous distortions usually in leaves ....*D. deformans.*

III. Spore balls with several irregular layers of spores, within which are hyphal threads; sori indefinite, hidden in leaf petioles............................*D. obscura.*

Doassansia opaca Setch. Figs. 19, 22, 29. The sori form in the leaves evident lead-colored pustules, about 2-5 mm., which show as slight elevations on both surfaces; they are more or less scattered, usually in yellowish or reddish brown widely discolored areas. The spore balls are closely compacted in a single layer, occupying most of the space between the epidermal layers of the leaf, and consist of a distinct cortex with a mass of fertile cells entirely filling the interior; they are oblong to subspherical or cuboidal, and 200-300μ in greatest length. The cortical cells are reddish brown, oblong or subcubical, prominent, about 14-27μ in length. The spores are rather loosely compacted, chiefly subspherical, 10-15μ in diameter.

Host and Distr.: *Sagittaria variabilis,* Norwich, Aug. 14, 1889 (Setchell); New Haven (Setchell); Whitneyville, Aug. 10, 1902; Montowese, Sept. 20, 1902; Westville, Sept. 8, 1904.

A portion of one of the spore balls is shown in cross section in Fig. 19.

Doassansia occulta (Hoffm.) Cornu. The sori occur in the ovaries, forming swollen, ovate bodies. The spore balls consist of a distinct cortex within which is a single layer of fertile cells surrounding a central mass of parenchymatous tissue; they are subspherical or more irregular, and 100-160μ in length. The cortical cells are polyhedral or more elongated tangentially, and 8-10μ in length. The spores adhere rather firmly, and are about 10-12μ in length.

Host and Distr.: *Potamogeton Pennsylvanicus,* Norwich, Aug. 26, 1889 (Setchell); Bridgeport (Morong).

Doassansia Martianoffiana (Thüm.) Schröt. In this species the sori occur in the leaves, forming unthickened, yel-

lowish or eventually reddish brown subcircular spots, which sometimes merge into indefinite areas. The spore balls are situated in the spongy parenchyma of the leaf, and consist of a distinct cortex surrounding a single layer of fertile cells within which is a central mass of sterile cells; they are chiefly subspherical or spherical, and 100-160μ in diameter. The cortical cells are brown and small. The spores are slightly yellowish tinted, chiefly polyhedral or slightly elongated radially, and 8-12μ in length.

Host and Distr.: *Potamogeton* sps., Norwich (Setchell); New Haven (Setchell); Simsbury (Setchell); Whitneyville, Aug. 18, Sept. 21, 1902; Westville, Sept. 8, 1904.

Doassansia deformans Setch. The sori occur in various parts of the host, usually in the leaves, where they form conspicuous distortions in the midribs and petioles. The spore balls occur in the intercellular spaces, and consist of a cortical layer surrounding a single layer of fertile cells within which is a central mass of sterile cells; they are chiefly subspherical, and vary from 100-140μ in diameter. The cortical cells are polyhedral, occasionally slightly elongated tangentially, small, about 4-6μ by 8-12μ. The spores are ovoid to polyhedral, rather firmly united, and chiefly 8-12μ, rarely 15μ, in length.

Host and Distr.: *Sagittaria variabilis,* Norwich, Aug. 17, 1889 (Setchell); New Haven (Setchell).

This species was originally described by Setchell from Connecticut material.

Doassansia obscura Setch. The sori are obscured, the spore balls being hidden in the interior of the basal parts of the petioles without especial discoloration or distortion. The spore balls are arranged in a single row in the air chambers of the host, and consist of a distinct cortex surrounding several irregular layers of spores and a central mass of indefinite fungal hyphæ; they are oblong to subspherical, and of very large size, 150-300μ in length. The conspicuous cortical cells are light brown, ovoid to obovate or subcordate, and 12-18μ by 8-12μ. The spores are chiefly subspherical and small, 8-12μ in diameter.

Host and Distr.: *Sagittaria variabilis,* Norwich, Sept. (Setchell).

Setchell described this species originally from Connecticut and Massachusetts. This is the only collection reported for this state; the fungus is so hidden in the host that it is not easily detected.

Tracya Syd.

The sori occur permanently embedded in the tissue of the leaves (fronds). The spore balls are destitute of a cortical layer, and consist of a single layer of spores enclosing a network of septate filaments. The spores are hyaline or yellowish, firmly united, and of small to medium size. Fig. 20.

This genus, first described by Setchell under the name *Cornuella,* contains a single species, which has been reported only from North America and on a single species of duckweed. It is closely related to *Doassansia,* but lacks the sterile cortex.

Tracya Lemnæ (Setch) Syd. Fig. 20. The sori occur in the languishing fronds, showing the spore balls under a hand lens as minute, clustered or scattered, opaque embedded bodies. The spore balls are situated in the spongy parenchyma above the lower epidermis, are subspherical and rather small, 50-100μ in diameter. The spores are yellowish, firmly compacted, cuboidal, polyhedral or often more elongated radially, and chiefly 10-12μ in length; they arise from the ends of the sterile network of brownish hyphæ that fill the interior.

Host and Distr.: *Spirodela polyrrhiza,* New Haven (Setchell); Whitneyville, Oct., 1902.

This is one of the most interesting species of the Ustilagineæ. So far it has been reported only from four states. As in *Doassansia,* sections of the infected tissue are necessary to make out the structure of the fungus. Fig. 20 shows merely a portion of the spore ball in cross section.

LIST OF HOSTS, ACCORDING TO FAMILIES.

MONOCOTYLS.

NAIADACEÆ.

Potamogeton Pennsylvanicus.
Doassansia occulta.
Potamogeton sps.
Doassansia Martianoffiana.

ALISMACEÆ.

Sagittaria variabilis.
Doassansia deformans.
Doassansia obscura.
Doassansia opaca.

GRAMINEÆ.

Agrostis alba var. **vulgaris.**
Ustilago striæformis.
Andropogon scoparius.
Sorosporium ? Ellisii.
Sorosporium Everhartii.
Anthoxanthum odoratum.
Tilletia Anthoxanthi.
Arrhenatherum avenaceum.
Ustilago perennans.
Avena sativa.
Ustilago Avenæ.
Ustilago levis.
Cenchrus tribuloides.
Sorosporium Syntherismæ.
Eragrostis major.
Ustilago spermophora.
Euchlæna luxurians.
Ustilago Zeæ.
Glyceria grandis.
Ustilago longissima.
Holcus lanatus.
Entyloma crastophilum.
Hordeum vulgare.
Ustilago Hordei.
Ustilago nuda.
Panicum Crus-galli.
Tolyposporium bullatum.
Ustilago Crus-galli.
Ustilago sphærogena.
Panicum sanguinale.
Ustilago Rabenhorstiana.
Panicum virgatum.
Tilletia Maclagani.
Phleum pratense.
Ustilago striæformis.
Phragmites communis.
Neovossia Iowensis.
Secale cereale.
Urocystis occulta.
Setaria glauca.
Ustilago Panici-glauci.
Setaria Italica.
Ustilago Crameri.
Sorghum vulgare and vars.
Sphacelotheca Sorghi.
Zea Mays.
Ustilago Zeæ.
Zizania aquatica.
Entyloma lineatum.

CYPERACEÆ.

Carex Pennsylvanica.
Cintractia Caricis.
Schizonella melanogramma.
Cyperus filiculmis.
Cintractia Cyperi.
Rhynchospora alba.
Cintractia Montagnei.

LEMNACEÆ.

Spirodela polyrrhiza.
Tracya Lemnæ.

ERIOCAULACEÆ.

Eriocaulon septangulare.
Ustilago Eriocauli.

JUNCACEÆ.

Juncus tenuis.
Cintractia Junci.

LILIACEÆ.

Allium Cepa.
Urocystis Cepulæ.

AMARYLLIDACEÆ.

Hypoxys erecta.
Urocystis Hypoxyis.

DICOTYLS.

POLYGONACEÆ.

Polygonum acre.
Sphacelotheca Hydropiperis.
Polygonum Convolvulus (?)
Ustilago anomala.
Polygonum dumetorum var. **scandens.**
Ustilago anomala.
Polygonum Hydropiper.
Ustilago utriculosa.
Polygonum hydropiperoides.
Ustilago utriculosa.
Polygonum lapathifolium.
Ustilago utriculosa.
Polygonum Pennsylvanicum.
Ustilago utriculosa.

Polygonum sagittatum.
Sphacelotheca Hydropiperis.
NYMPHÆACEÆ.
Nuphar advena.
Entyloma Nymphææ.
Nymphæa odorata.
Entyloma Nymphææ.
RANUNCULACEÆ.
Anemone nemorosa.
Urocystis Anemones.
Thalictrum polygamum.
Entyloma Thalictri.
OXALIDACEÆ.
Oxalis stricta.
Ustilago Oxalidis.
SOLANACEÆ.
Physalis pubescens.
Entyloma Physalidis.
Physalis Virginiana.
Entyloma Physalidis.
SCROPHULARIACEÆ.
Linaria vulgaris.
Entyloma Linariæ.
Veronica peregrina.
Entyloma Linariæ var. *Veronicæ.*
CAMPANULACEÆ.
Lobelia inflata.
Entyloma Lobeliæ.
COMPOSITÆ.
Ambrosia artemisiæfolia.
Entyloma polysporum.

EXPLANATION OF FIGURES.

Figs 1-20. Spores of various smuts, part of which are shown in optical cross section. Magnified about 650 diameters except where otherwise stated.

Fig. 1. *Ustilago longissima* from *Glyceria grandis.*

Fig. 2. *Ustilago Zeæ* from *Zea Mays.*

Fig. 3. *Ustilago Oxalidis* from *Oxalis stricta.*

Fig. 4. *Ustilago utriculosa* from *Polygonum Pennsylvanicum.*

Fig. 5. *Sphacelotheca Sorghi* from *Sorghum vulgare; a,* sterile cells of false membrane.

Fig. 6. *Sphacelotheca Hydropiperis* from *Polygonum sagittatum; a,* sterile cells of false membrane.

Fig. 7 *Sorosporium Syntherismæ* from *Cenchrus tribuloides; a,* spore ball magnified only about 100 diameters.

Fig. 8. *Cintractia Caricis* from *Carex Pennsylvanica.*

Fig. 9. *Schizonella melanogramma* from *Carex Pennsylvanica.*

Fig. 10. *Tolyposporium bullatum* from *Panicum Crus-galli; a,* spore ball magnified only about 100 diameters.

Fig. 11. *Tilletia Maclagani* from *Panicum virgatum.*

Fig. 12. *Tilletia Anthoxanthi* from *Anthoxanthum odoratum; a,* sterile cell.

Fig. 13. *Neovossia Iowensis* from *Phragmites communis.*

Fig. 14. *Urocystis Cepulæ* from *Allium Cepa.*

Fig. 15. *Urocystis occulta* from *Secale cereale.*

Fig. 16. *Entyloma lineatum* from *Zizania aquatica.*

Fig. 17. *Entyloma Lobeliæ* from *Lobelia inflata.*

Fig. 18. *Entyloma Nymphææ* from *Nymphæa odorata.*

Fig. 19. *Doassansia opaca* from *Sagittaria variabilis.* This is a cross section of a spore ball merely showing one end; *a,* superficial cortex of sterile cells; *b,* spores filling the interior of ball.

Fig. 20. *Tracya Lemnæ* from *Spirodela polyrrhiza.* This is a cross section of a spore ball merely showing one end; *a,* superficial layer of spores; *b,* sterile hyphæ filling interior of ball.

Figs. 21-25. Germination of spores of smuts. Magnified about 650 diameters.

Fig. 21. Germination of spore of *Ustilago utriculosa* from *Polygonum Pennsylvanicum* in water; *a,* promycelium; *b,* sporidia.

Fig. 22. Germination of spore of *Doassansia opaca* from *Sagittaria variabilis* in water; *a,* promycelium; *b,* sporidia; *c,* secondary sporidia fallen off.

Fig. 23. Germination of spore of *Ustilago Avenæ* from *Avena sativa* in horse dung; *a,* promycelium; *b,* infection threads.

Fig. 24. Germination of a sporidium of *Ustilago Sorghi* into an infection thread.

Fig. 25. Small portion of a group of sporidia developed from promycelium of *Tolyposporium Eriocauli* in potato agar.

Fig. 26. Cross section of epicotyl of broom corn infected by *Ustilago Sorghi; a,* epidermal cells; *b,* parenchyma cells of cortex; *c,* woody cells of central cylinder, and *d,* mycelium of the fungus ramifying through the parenchyma cells of the cortex. Magnified about 125 times.

Figs. 27-55. Sori of various smuts, showing general appearance and parts of different hosts infected. Natural size except where otherwise indicated.

Index.

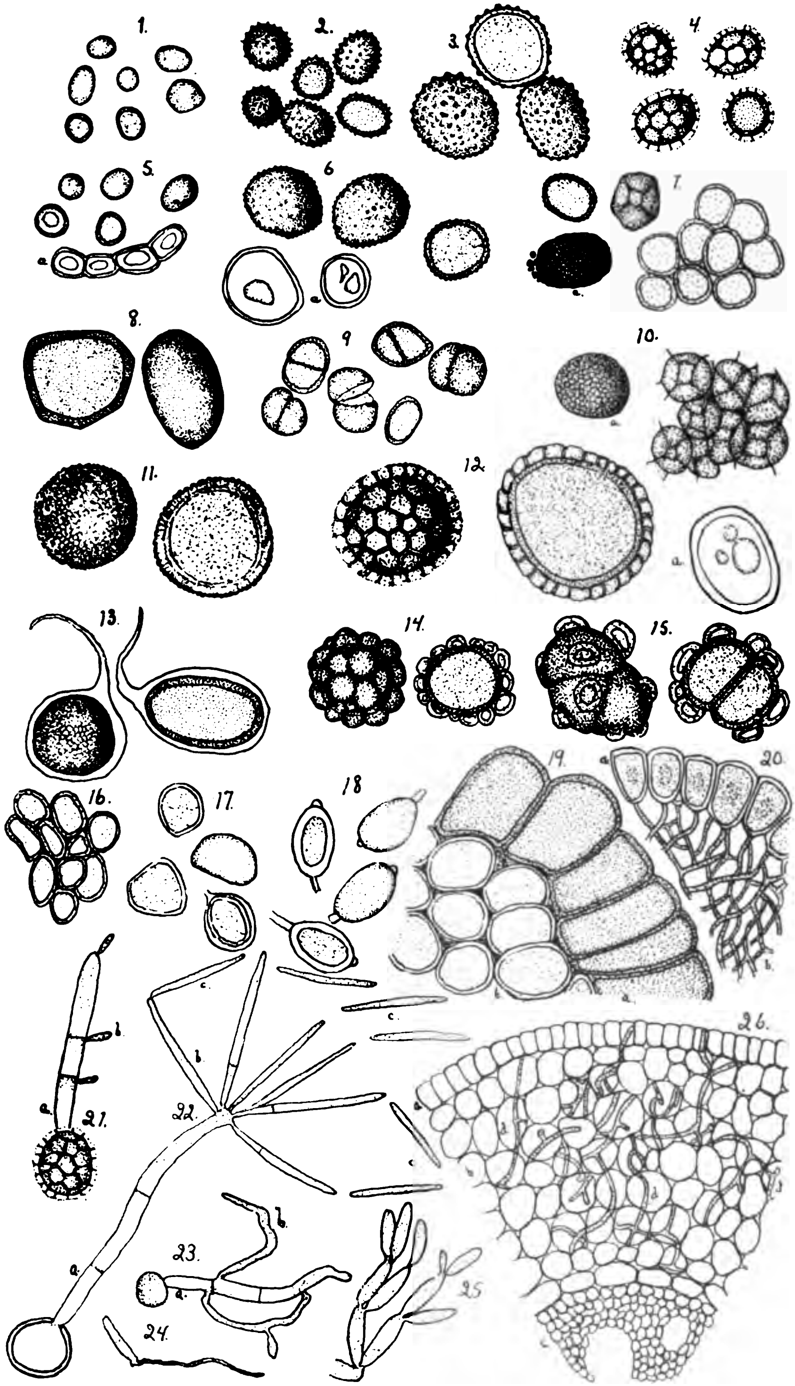

1.
2.
3.
4.
5.
6
7.
8.
9
10.
11.
12.
13.
14.
15.
16.
17.
18
19.
20.
21.
22.
23.
24.
25
26.

Fig. 27, p. 24.

Cintractia Caricis × 2.

Fig. 28, p. 25.

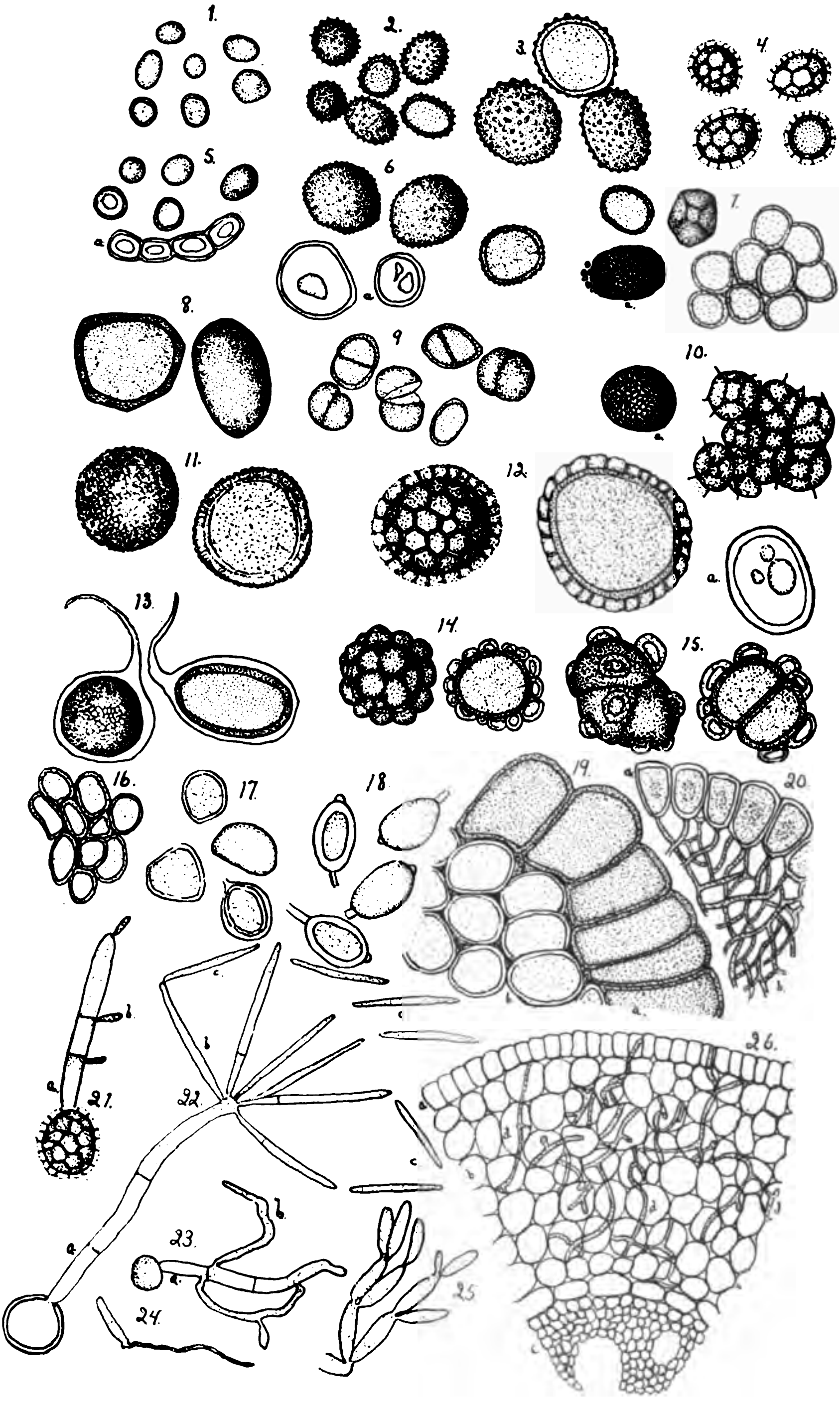
Cintractia Junci × 2.

Fig. 29, p. 38.

Doassansia opaca.

Fig. 30, p. 36.

Entyloma Linariæ.



1.
2.
3.
4.
5.
6
7.
8.
9
10.
11.
12.
13.
14.
15.
16.
17.
18.
19.
20.
21.
22.
23.
24.
25.
26.

Fig. 27, p. 24.

Cintractia Caricis × 2.

Fig. 28, p. 25.

Cintractia Junci × 2.

Fig. 29, p. 38.

Doassansia opaca.

Fig. 30, p. 36.

Entyloma Linariæ.

Fig. 31, p. 35.

Entyloma Lobeliæ × 2.

Fig. 32, p. 34.

Entyloma lineatum.

Fig. 33, p. 37.

Entyloma Nymphææ

Fig. 34, p. 35.

Entyloma Physalidis.

Fig. 35, p. 25.

Schizonella melanogramma × 2.

Fig. 36, p. 27.

Sorosporium Syntherismæ.

Fig. 37, p. 22.

Sphacelotheca Hydropiperis × 2.

Fig. 38, p. 22.

Sphacelotheca Sorghi × 2.

Fig. 39, p. 29.

Tilletia Anthoxanthi × 2.

Fig. 40, p. 28.

Tolyposporium bullatum × 2.

Fig. 41, p. 32.

Urocystis occulta.

Fig. 42, p. 31.

Urocystis Cepulæ.

Fig. 43, p. 16.

Ustilago Avenæ.

Fig. 44, p. 15.

Ustilago Crameri.

Fig. 45, p. 15.

Ustilago levis.

Fig. 46, p. 15.

Ustilago Hordei.

Fig. 47, p. 16.

Ustilago nuda.

Fig. 48, p. 20.

Ustilago Oxalidis × 2.

49, p. 17.

Panici-glauci.

Fig. 50, p. 17.

U. Rabenhorstiana.

Fig. 51, p. 19.

U. striæformis.

Fig. 52, p. 18.

Ustilago spermophora × 2.

g. 53, p. 18.

U. sphærogena.

Fig. 54, p. 21.

U. utriculosa.

Fig. 55, p. 19.

U. Zeæ ÷ ½.

-910